MEMOIRS

ON

THE NERVOUS SYSTEM.

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Professor Warren
with the very kind regards
of the Author

MEMOIRS

ON

THE NERVOUS SYSTEM.

BY

MARSHALL HALL, M.D. F.R.S. L. & E. &c. &c.

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PREFACE.

As THE subject of the following pages is every day exciting greater interest, and assuming greater importance, and as I wish to claim neither more nor less than is justly due to me, I think it right to insert, in this place, two short communications made to the Zoological Society, and brief notices of my subsequent publications.

The *first* was made on November the 27th, 1832. The following is an extract from the Proceedings of the Committee of Science:

"A paper was read, containing 'a brief account of a particular function of the nervous system,' in which Dr. Marshall Hall detailed a series of experiments tending to prove the existence of a source of muscular action distinct from all those hitherto noticed by physiologists: viz. volition, the irritation of the motor nerves in some part of their origin or course, or that of the muscles themselves. The peculiarity of this motion he stated to consist in its being excited by irritation of the extreme portion of the sentient nerves, whence the impression is conveyed through the corresponding portion of brain and spinal marrow as a centre, to the extremities of the motor nerves.

"The animals experimented on were salamanders, frogs, and turtles. In

the first of these the tail, entirely separated from the body, moved as in the living animal, on being excited by the point of a needle passed lightly over its surface. The motion ceased on destroying the spinal marrow within the caudal *vertebræ*. The head of a frog having been removed, and the spine divided between the third and fourth *vertebræ*, an eye of the separated head was touched: it was retracted and the eye-lid closed,—a similar movement being observed in the other eye. On removing the brain these phenomena ceased. On pinching the skin or the toe of one of the anterior extremities, the whole of this portion of the animal moved. On destroying the spinal marrow this phenomenon also ceased. Precisely similar effects were observed on pinching the skin or toe of one of the posterior extremities; and on removing the last portion of the spinal marrow this phenomenon ceased. The head of the turtle continues to move long after its separation from the body: on pinching the eye-lid it is forcibly closed; the mouth is opened, and the membrane expanded under the lower jaw descends as in respiration. On pinching any part of the skin of the body, extremities, or tail, the animal moves. The posterior extremities and tail being separated together, the former were immoveable; the latter moved on the application of the flame of a lighted taper to the skin. Those extremities had no connection with the spinal marrow. All movement ceased in the tail also on withdrawing the spinal marrow from its canal.

"'Three things,' Dr. Hall observes, 'are plain from these observations: 1. that the nerves of sensibility are impressible in portions of an animal separated from the rest; in the head, in the upper part of the trunk, in the lower part of the trunk: 2. that motions similar to voluntary motions follow these impressions made upon the sentient nerves: and 3. that the presence of the spinal marrow is essential as the central and cementing link between the sentient and motor nerves.'

"Dr. Hall then proceeded to adduce another series of experiments still

more conclusive. If a frog be made to swallow a watery solution of opium, it becomes affected with symptoms very similar to those of tetanus and hydrophobia; the body and limbs become rigidly extended; but besides this state of spasm, the cutaneous nerves become extremely susceptive, and the motor nerves extremely excitative; a shake, a touch, a breath of air even, induces spasmodic movements of the body and limbs. A frog made tetanic by opium was decapitated and divided just below the third *vertebra*. The eyes continued drawn in, and no motion could be detected on irritating the eye, eye-lid, or skin. But both the anterior and posterior parts remained tetanic as before. The limbs were moved in the same spasmodic manner by the same slight impressions. The exalted condition of the function of the sentient and motor nerves continued in each part. All was changed on removing the brain and the respective portions of spinal marrow. The eyes were immovable, but no longer retracted; the muscles of the limbs were flaccid, and there was no evidence of irritability in the sentient nerves.

" 'These experiments,' Dr. Hall continued, 'appear to me to establish a property or function of the nervous system,—of the sentient and motor nerves,—*distinct from sensation and voluntary or instinctive motion.* However doubtful this conclusion might appear in reference to the first series of experiments upon the animal in its natural state, it can scarcely admit of doubt when we compare with them the phenomena observed in the frog made tetanic by opium. In this case the contraction of the muscles is plainly *not* the result of volition; and it obeys the same laws, in regard to its continuance and extinction, as the similar function or property in its natural and unexalted state. Neither does it arise from the irritation of the motor nerves, or muscular fibre; for it ceases on removing the spinal marrow, while the property of irritability continues unimpaired after the destruction of the nervous centre. I conclude, then, that there is a pro-

perty of the sentient and motory system of nerves which is independent of sensation and volition ;—a property of the motor nerves independent of immediate irritation :—a property which attaches itself to any part of an animal, the corresponding portion of the brain and spinal marrow of which is entire. This property is capable of exaltation, in the frog, from the influence of opium, and doubtless of strychnine; and I may add, that it is diminished or extinguished by the hydrocyanic acid. It is naturally greatest in animals of lowest *sensibility*, as the cold-blooded.'

" With regard to the office performed by this property of the nervous system in the animal economy, Dr. Hall stated that it appeared especially to preside over all those functions which, from appearing neither exclusively voluntary nor independent of the will, have been designated mixed. That the function of respiration is of this kind he considered plain from the phenomena presented by the separated head of the turtle, in which the submaxillary integuments became alternately inflated and contracted as in ordinary respiration. The actions of coughing, sneezing, vomiting, &c., are of the same kind. So apparently is the singular effect produced by tickling. Of all the parts of the human frame the *larynx* and the *anus* appear to be most under the influence of this peculiar power. No part is so impatient of irritation as the former; none so much in need of automatic action as the latter, with the other sphincters. These very parts are subject moreover to peculiar morbid affections of this function: in regard to the *larynx* it is observed in some affections of dangerous tendency referred to spasm: in the sphincters it is seen in those singular and painful affections termed strangury and tenesmus. There are also peculiar affections of the system of voluntary muscles referrible to the same property. In hydrophobia and tetanus, in each of which the extremities of the sentient nerves have been wounded, there is a peculiar exaltation of this function: the morbid action appears to be propagated to the spinal marrow; and then

along the motor nerves, producing those dreadful sensations and spasms so fearfully characteristic of these affections. The least external shock or impression is terrible; the immediate muscular contractions are intolerable."

The *second* was read on August the 12th, 1834. The following account is extracted from the "Proceedings:"

"Dr. Marshall Hall showed some experiments in the decapitated *turtle*. Irritation of the nostrils, *larynx*, and spinal marrow, induced acts of inspiration; that of the fins and tail induced movements of the other parts respectively.

"But the principal object of Dr. Hall was to show that irritation of the nerves themselves equally induced movements of the limbs, &c. When either the sentient or the motory branch of the lateral spinal nerves was stimulated, motions were induced in all the limbs. Dr. Hall stated that a movement of inspiration and of deglutition was caused in the *donkey* by irritation of the eighth pair of nerves. It has been already stated that irritation of the nostrils, or the branches of the fifth pair of nerves, induced inspiratory acts in the *turtle*. From these and other facts, Dr. Hall is induced to consider the functions of these two nerves as similar. He further observed that both are nerves of secretion, and that both are muscular nerves —if the minor portion of the fifth, and the accessory, be included—as well as *excitors of respiration;* the fifth differs chiefly in being sentient, being distributed to external as well as internal surfaces. With the fifth and eighth, Dr. Hall associates other spinal nerves. He considers respiration as a part of a general function of the nervous system, which presides over the *larynx*, *pharynx*, sphincters, ejaculators, &c., to which he has given the name of reflex, from its consisting of impressions carried to and from the *medulla oblongata* and *medulla spinalis*. Some illustrations of this function were given by Dr. Hall at the Meeting of the Committee of Science and Corre-

spondence on November 27, 1832, (Proceedings, Part ii. p. 190,) and further illustrations of it have formed the subject of a paper by him, which has since been published in the 'Philosophical Transactions.' The experiments shown on the present occasion demonstrate the existence of a series of physiological facts at variance with the law laid down by M. Müller in his paper entitled, 'Nouvelles Expériences sur l'effet que produit l'Irritation mécanique et galvanique sur les racines des nerfs spinaux : par Jean Müller, Professeur a l'Université de Bonn,' and published in the 'Annales des Sciences Naturelles,' tom. xxiii. (1831), p. 95, viz. : 'Il suit encore qu'il y a des nerfs qui n'ont point de force *motrice* ou *tonique*, qui ne peuvent jamais occasionner des mouvemens par eux-mêmes, qu'ils soient irrités par l'action galvanique ou mécanique, et qui ne conduisent le courant galvanique que passivement, comme toutes les parties molles humides ; qu'il y a en revanche des *nerfs moteurs* ou *toniques (nervi motorii seu tonici)* qui montrent à chaque irritation médiate ou immédiate leur force tonique, *qui agit toujours dans la direction des branches des nerfs et qui n'agit jamais en arrière.*' In Dr. Hall's experiments the influence first pursued an '*arrière*' course to the spinal marrow, being afterwards reflected upon the muscles.

"Dr. Hall next observed, in regard to respiration, that, whilst Sir Charles Bell contends that it is involuntary, and Mr. Mayo that it is voluntary, the old doctrine of its being mixed, or partaking of both properties, is the true one. He founded this view upon the following facts :

"1. If the *cerebrum* be removed, respiration continues as an involuntary function through the agency of the eighth pair of nerves ;

"2. If the eighth pair be divided, respiration equally continues, but as an act of volition ; but

"3. If the *cerebrum* be first removed, and the eighth pair be then divided, respiration ceases on the instant. Volition is first removed with the *cerebrum* ; the influence of the eighth pair is then removed by its divi-

sion. The two sources of the mixed or double function being both cut off, the function ceases.

"Dr. Hall explains and reconciles in this manner the difficult and apparently contradictory facts,—that the *medulla oblongata* alone, above the origin of the eighth pair of nerves, or the eighth pair of nerves themselves, may be divided, without arresting the respiration; but that the *medulla oblongata* cannot be divided at the origin of these nerves without arresting the respiration instantly. In the first case the agency of volition is alone removed, and the respiration continues through the influence of the eighth pair; in the second, that of the eighth pair is removed, and the respiration continues as a function of volition; but in the third, both influences are destroyed at once, and with them the mixed or double function.

"The same mixed or double character belongs to the other parts of the reflex function, as that of the *larynx*, the sphincters, the ejaculators. All the organs of the reflex function are also alike impressed through the medium of the mental affections or passions.

"The course of the influence which constitutes the reflex function must be divided into the incident, or that into the *medulla*, and the reflected, or that from the *medulla*. The nerves which conduct the incident impression have, hitherto, received no designation; the others constitute a part of the system of muscular nerves. To the former class belong nerves which doubtless supply the *larynx* with its impressibility by carbonic acid, &c. &c., and hitherto undescribed, untraced; to the latter, the superior and inferior laryngeals: to the former belong the fifth, in the nostrils, in the face, —the eighth in the lungs, &c.; to the latter the respiratory nerves; to the former, nerves hitherto undescribed of the sphincters, ejaculators, &c.; to the latter, the muscular nerves supplying these parts.

"The whole constitutes the subject of an investigation in which Dr. Hall has been for some time engaged."

My next publications on this subject were a Course of Lectures, delivered from a printed syllabus, in the summer, and repeated in the winter, of 1835, of which one was inserted in the Medical Gazette for January, 1836, and the whole in my "Lectures on the Nervous System and its Diseases," published in April of that year.

POSTSCRIPT.

October, 1837.

During the *four years*, which elapsed between the publication of my first and second Memoirs, the subject of this Volume was treated with opposition or neglect. That it has been rescued from this treatment is, I believe, mainly due to the just influence of an illustrious foreigner. The sanction of Prof. Müller to the truth, importance, and originality of this discovery, I feel to be of the utmost value to the progress of the Inquiry.

But there is now a danger lest the discovery itself should, inadvertently, be partly assigned to the distinguished physiologist whom I have mentioned [1]. I think it right, therefore, to state very distinctly, that whatever credit does attach to this discovery, and, in one word, to *all* the points comprised in p. 112—113, is certainly and entirely due to me.

1. My first publication upon this subject, in the Proceedings of the Zoological Society, actually *preceded* Prof. Müller's first publication, in his Handbuch der Physiologie, (p. 333,) the dates being respectively, November 1832, and the Spring of 1833.

2. Prof. Müller includes the *brain*, and even the *sympathetic*, (loc. cit.) with the spinal marrow, as agents of the *reflex motions;* and he does *not* distinguish the *principle* of these motions from *sensation*. It is almost needless to repeat, that I have, on the contrary, demonstrated that the *spinal marrow*, distinguished from the *brain*, from the spinal *chord*, and from the *sympathetic*, is the sole organic seat of this function; that the principle

[1] See Observations on the Structure and Functions of the Spinal Chord, by R. D. Grainger, Lecturer on Anatomy and Physiology; p. iv. 8; &c. &c.

of this function is, at once, *distinct* from sensation, and *identical* with another property of the nervous system,—long imperfectly known to physiologists, yet hitherto, strange to say, *unapplied* to Physiology,—designated by Haller, the *vis nervosa*, and by Prof. Müller himself, the *vis motoria*, and now the excito-motory property or power.

3. I have discovered and demonstrated new modes of action of this power, modes at variance with the views of Haller, and the *laws* laid down by Prof. Müller, and have *identified* it with the principle which acts when, the spinal marrow being divided, one of the lower extremities is stimulated, —a second principle known to physiologists, yet *unapplied* to physiology! I have made it probable that it acts through a *true spinal marrow*, and a *distinct and peculiar system of nerves*, the existence of which had not been even suspected before.

4. I have designated the system by terms which Prof. Müller, entertaining the opinions which he does, could not use. The terms *true spinal* and *excito-motory*, express views at variance with those held by Prof. Müller.

5. Lastly, I have traced the excito-motory principle through its anatomical, physiological, pathological, and therapeutic relations, in a manner and degree not attempted by Prof. Müller.

It is singular that Prof. Müller does not always appear aware of the existence of this function: my reader may *compare* p. 333—, 479—, and 688—, of the Handbuch der Physiologie.

The candid inquirer will readily admit, from these considerations, that Prof. Müller has no claim to participate in this discovery; whilst, on the other hand, he will acknowledge that the investigation is infinitely indebted to him for the sanction of his approbation and authority, justly the highest in Physiology in the present day.

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MEMOIR I.

ON THE

REFLEX FUNCTION

OF THE

MEDULLA OBLONGATA AND MEDULLA SPINALIS.

ON THE

REFLEX FUNCTION

OF THE

MEDULLA OBLONGATA AND MEDULLA SPINALIS[1].

Sect.—I. *Introduction.*

1. In the present Memoir, I propose to give an account of a principle of action in the animal economy, which has not hitherto, I think, been distinguished with sufficient precision from the other vital and animal functions.

2. The principle to which I have adverted is connected, in a peculiar manner, with the medulla oblongata and the medulla spinalis. There is still much discrepancy of opinion amongst physiologists, in regard to the properties and functions of these parts of the nervous system. Legallois concluded, from his interesting series of experiments, that the spinal marrow, as a whole, and in distinct portions, is the exclusive source of sensation and voluntary motion. He observes[2], "La vie du tronc dépend de la moëlle épinière, et celle de chaque partie dépend spécialement de la portion

[1] *Read before the* Royal Society, *on June the* 20*th*, 1833.

[2] Œuvres de Legallois, Paris, 1824, tome i. p. 62.

de cette moëlle dont elle reçoit ses nerfs. De plus, il est facile de démontrer que cette prérogative de la moëlle épinière, d'être la source du sentiment et de tous les mouvemens volontaires du tronc, lui appartient exclusivement à tout autre organe." The Reporters of the Institute adopt the conclusions of Legallois: "M. Legallois," they observe [1], "a démontré que la section de la moëlle épinière sur les premières ou sur les dernières vertèbres cervicales, n'arrête que les mouvemens inspiratoires, et qu'elle laisse subsister dans tout le corps le sentiment et les mouvemens volontaires. Cette distinction est capitale: personne ne l'avait faite avant lui [2]." M. Cruveilhier, on the other hand, denounces this view of the functions of the spinal marrow as one of the errors of modern physiology. He observes [3], "L'indépendence des diverses parties de la moëlle les unes des autres, l'indépendence de la moëlle du cerveau, assez généralement admise dans ces derniers temps, me parait une grave erreur physiologique fondée sur d'ingénieuses expériences. L'opinion des anciens, qui regardaient la moëlle comme un gros cordon nerveux destiné à répondre lui seul à tous les nerfs de l'économie, pour transmettre en définitive au cerveau les impressions, ou pour en recevoir les impulsions volontaires ou organiques, cette opinion est bien plus en harmonie avec les faits, avec la grande loi anatomique de la continuité du système nerveux."

3. It will not be difficult to prove that the conclusions of Legallois and the Reporters of the Institute, are not legitimate deductions from the facts

[1] Œuvres de Legallois, Paris, 1824, tome i. p. 251.

[2] More recently, M. Magendie, M. Lallemand, and M. Ollivier have repeated the same opinion: Anatomie des Systèmes Nerveux, &c. par A. Desmoulins, Paris, 1825, p. 561, &c.; Observations Pathologiques propres à éclairer la Physiologie, ed. 2, Paris, 1825, pp. 88. 96, &c.; Traité de la Moëlle Epinière, ed. 2, Paris, 1827, p. 17, &c. The subject is unnoticed by M. Serres: Anatomie Comparée du Cerveau, Paris, 1824. The physiologists of our own country have adopted the same views: Philip on the Vital Functions, ed. 3, p. 120; Mayo's admirable Outlines of Human Physiology, ed. 3, p. 227-231, &c.

[3] Anatomie Pathologique, Fasc. III.

before them. But M. Cruveilhier altogether overlooks these facts, which are amongst the most interesting in physiology, and adopts an opinion which, however true, is far too exclusive.

4. On the more recent occasion of a report upon the admirable work of M. Flourens, the perpetual Secretary of the Institute states his opinion on this point in a manner far more problematical. "L'auteur," he observes, "conclut que la sensation et la contraction n'appartiennent plus à la moëlle épinière qu'aux nerfs; et cette conclusion est certaine pour les animaux entiers. Ce serait une grande question de savoir si elle l'est également pour les animaux qui ont perdu leur encéphale, et qui, dans certaines classes, paraissent loin de perdre sur-le-champ leurs fonctions animales [1]."

5. It was a singular mistake to imagine that the same conclusion could be just in reference to the entire animal, which was incorrect in reference to the animal deprived of its encephalon. The facts are these: in the entire animal, sensation and voluntary motion, functions of the cerebrum, combine with the functions of the medulla oblongata and medulla spinalis, and may therefore render it difficult or impossible to determine those which are peculiar to each; if, in an animal deprived of the brain, the spinal marrow, or the nerves supplying the muscles, be stimulated, those muscles, whether voluntary or respiratory, are equally thrown into contraction, and, it may be added, equally in the complete and in the mutilated animal; and, in the case of the nerves, equally in limbs connected with and detached from the spinal marrow.

6. The operation of all these various causes of muscular contraction may be designated *centric*, as taking place *at*, or at least in a direction *from*, central parts of the nervous system. But there is another function the phenomena of which are of a totally different order, and obey totally different

[1] Du Système Nerveux, par P. Flourens, Paris, 1824, p. 70.

laws, being excited by causes in a situation which is *eccentric* in the nervous system; that is, distant from the nervous centres. This mode of action has not, I think, been hitherto distinctly understood by physiologists. It is involved in the question which Baron Cuvier considers as so full of interest, and is that treated of in the following pages.

7. Many of the phenomena of this principle of action, as they occur in the limbs, have certainly been observed. But, in the first place, this function is by no means confined to the limbs; for, whilst it imparts to each muscle its appropriate tone, and to each system of muscles its appropriate equilibrium or balance, it performs the still more important office of presiding over the orifices and terminations of each of the internal canals in the animal economy, giving to them their due form and action; and, in the second place, in the instances in which the phenomena of this function have been noticed, they have been confounded, as I have stated, with those of sensation and volition; or, if they have been distinguished from these, they have been too indefinitely denominated sympathetic, instinctive, automatic. I have been compelled, therefore, to adopt some new designation for them, and I shall now give the reasons for my choice of that which is given in the title of this paper.

8. This property is characterized by being *excited* in its action, and *reflex* in its course: in every instance in which it is exerted, an impression made upon the extremities of certain nerves is conveyed to the medulla oblongata or the medulla spinalis, and is reflected along other nerves to parts adjacent to, or remote from, that which has received the impression.

9. It is by this reflex character that the function to which I have alluded is to be distinguished from every other. There are, in the animal economy, four modes of muscular action, of muscular contraction. The *first* is that designated *voluntary:* volition, originating in the cerebrum, and spontaneous in its acts, extends its influence along the spinal marrow and the motor

nerves, in a *direct line*, to the voluntary muscles. The *second* is that of the *respiration:* like volition, the motive influence in respiration passes in a *direct line* from one point of the nervous system to certain muscles; but as voluntary motion seems to originate in the cerebrum, so the respiratory motions originate in the medulla oblongata: like the voluntary motions, the motions of respiration are *spontaneous* [1]; they continue, at least, after the eighth pair of nerves has been divided [2]. The *third* kind of muscular action in the animal economy is that termed *involuntary:* it depends upon the principle of irritability, and requires the *immediate* application of a stimulus to the nervo-muscular fibre itself. These three kinds of muscular motion are well known to physiologists; and I believe they are all which have been hitherto pointed out. There is, however, a *fourth*, which subsists, in part, after the voluntary and respiratory motions have ceased by the removal of the cerebrum and medulla oblongata, and which is attached to the medulla spinalis, ceasing itself when this is removed, and leaving the irritability undiminished. In this kind of muscular motion, the motive influence does not originate in any central part of the nervous system, but at a distance from that centre: it is neither spontaneous in its action, nor direct in its course; it is, on the contrary, *excited* by the application of appropriate stimuli, which are not, however, applied immediately to the muscular or nervo-muscular fibre, but to certain membranous parts, whence the impression is carried to the medulla, *reflected*, and reconducted to the part impressed, or conducted to a part remote from it, in which muscular contraction is effected.

10. The first three modes of muscular action are known only by actual movements or muscular contractions. But the reflex function exists as a continuous muscular action, as a power presiding over organs not actually in

[1] For my present views on this subject, see Memoir II. § 126, &c.
P. S. This is not true of *fishes*. See Desmoulins, Opus cit. t. ii. p. 745.

a state of motion, preserving in some, as the glottis, an open [1], in others, as the sphincters, a closed form, and in the limbs, a due degree of equilibrium, or balanced muscular action,—a function, not, I think, hitherto recognized by physiologists.

11. The three kinds of muscular motion hitherto known may be distinguished in another way. The muscles of voluntary motion and of respiration may be excited by stimulating the nerves which supply them, in any part of their course, whether at their source, as a part of the medulla oblongata or medulla spinalis, or exterior to the spinal canal: the muscles of involuntary motion are chiefly excited by the actual contact of stimuli. In the case of the reflex function alone, the muscles are excited by a stimulus acting mediately and indirectly in a curved and reflex course, along superficial sub-cutaneous or sub-mucous nerves proceeding to the medulla, and muscular nerves proceeding from the medulla. The first three of these causes of muscular motion may act on detached limbs or muscles. The last requires the connexion with the medulla to be preserved entire.

12. All the kinds of muscular motion may be unduly excited. But the reflex function is peculiar in being excitable into modes of action not previously subsisting in the animal economy, as in the cases of sneezing, coughing, vomiting, &c. The reflex function also admits of being permanently diminished or augmented, and of taking on some other morbid forms, of which I shall treat hereafter.

13. I shall thus have occasion to speak of the reflex function as the source of equilibrium in the muscular system; as excitable into various actions, which, however familiar, are not constant; and as assuming morbid forms.

14. Before I proceed to the detail of the experiments upon which this

[1] See Legallois, Op. cit. p. 176—178.

disquisition rests, it may be well to point out several instances in illustration of the various sources and modes of muscular action which have been enumerated. None can be more familiar than the act of swallowing. Yet how complicated is this act! The apprehension of the food by the teeth, the tongue, &c., is voluntary, and cannot, therefore, take place in an animal from which the cerebrum is removed [1]. The transition of the food over the glottis and along the middle and lower parts of the pharynx depends upon the reflex function: it can take place in animals from which the cerebrum has been removed [2], or the ninth pair of nerves divided [3]; but it requires the connexion with the medulla oblongata to be preserved entire [4]; and the actual contact of some substance which may act as a stimulus [5]: it is attended by the accurate closure of the glottis, and by the contraction of the pharynx. The completion of the act of deglutition is dependent upon the stimulus immediately impressed upon the muscular fibres of the œsophagus, and is the result of excited irritability.

15. The example which I have given is one of excited reflex function. The condition of the glottis during respiration, and that of the pharynx and of the sphincters at all times, except during the acts of deglutition, or of excretion, afford equally interesting and familiar examples of the permanent influence of that function. Whilst the nervous connexion between the larynx and the medulla oblongata is preserved entire,—in the rabbit (*Lepus cuniculus*), for example,—the glottis is preserved open, being slightly dilated during each act of inspiration; but if the inferior laryngeal nerves be di-

[1] Du Système Nerveux, par M. Flourens, Paris, 1824, p. 90. [2] Ibid.

[3] The Nervous System, by Charles Bell, F.R.S., 4to ed. 1830. Appendix, p. cxviii.

[4] De l'Usage de l'Epiglotte, par M. Magendie, Paris, 1813, pp. 6. 23, &c.

[5] This is the reason of our inability to perform the act of swallowing two or three times in rapid succession, without taking something into the mouth, or allowing time for the secretion of a portion of saliva. The reflex function must be excited into action by the contact of a stimulus. The act of swallowing cannot, therefore, be renewed, unless some substance, as saliva, be carried into contact with the pharynx. See further, § 111, and Memoir II. § 144—.

vided, the aperture immediately becomes so much diminished, that a state of excessive dyspnœa is induced. The sphincter ani, on the other hand, remains closed in the decapitated turtle (*Chelonia mydas*), if the lower part of the medulla spinalis be left in its canal; but it becomes immediately relaxed and open, if this part of the nervous system be withdrawn. The action of this muscle depends upon the medulla spinalis, and not upon the brain only.

16. However plain these observations may have made the fact, that there is a function of the nervous and muscular system distinct from sensation, from the voluntary and respiratory motions, and from irritability, it is right in every such inquiry as the present, that the statements and reasonings should be made with the experiment, as it were, actually before us. It has already been remarked, that the voluntary and respiratory motions are spontaneous acts, not necessarily requiring the agency of a stimulus. If, then, an animal can be placed in such circumstances that such motions will certainly not take place, the power of moving remaining, it may be concluded that volition and the motive influence of respiration are annihilated. Now this is effected by removing the cerebrum and the medulla oblongata. These facts are fully proved by the experiment of Legallois and M. Flourens, and by several which I proceed to detail, for the sake of the opportunity afforded by doing so, of stating the argument most clearly. See § 9, note 1.

17. I divided the spinal marrow of a very lively snake (*Coluber natrix*), between the second and third vertebræ. The movements of the animal were, immediately before, extremely vigorous and unintermitted. From the moment of the division of the spinal marrow, it lay perfectly tranquil and motionless, with the exception of occasional gaspings and slight movements of the head.

18. It became quite obvious that this state of quiescence would continue indefinitely, were the animal secured from all external impressions.

19. Being now stimulated, the body began to move with great activity, and continued to do so for a considerable time, each change of position or situation bringing some fresh part of the surface of the animal into contact with the table or other objects, and renewing the application of stimulus.

20. At length the animal became again quiescent; and being carefully protected from all external impressions, it moved no more, but died in the precise position and form which it had last assumed.

21. It requires a little manœuvre to perform this experiment successfully: the motions of the animal must be watched, and slowly and cautiously arrested by opposing some soft substance, as a glove or cotton wool; they are by this means gradually lulled into quiescence. If at this moment the figure last assumed be sketched upon paper, and the animal be left, protected from external impressions, it will be found to retain the same identical form when all vitality has ceased.

22. The slightest touch with a hard substance, the slightest stimulus, will, on the other hand, renew the movements of the animal in an active form. But that this phenomenon does not depend upon sensation, is further fully proved by the facts, that the position last assumed, and the stimuli applied, may be such as would be attended by extreme or continued pain, if the sensibility were undestroyed: in one case the animal remained partially suspended over the acute edge of the table; in others the previous infliction of punctures, and the application of a lighted taper, did not prevent the animal, still possessed of active powers of motion, from passing into a state of complete and permanent quiescence.

23. The same observations were made upon various other animals—the turtle, the viper (*Vipera Berus*), the toad (*Bufo vulgaris*), the frog (*Rana temporaria*), the eft (*Triton cristatus*), &c. It may therefore be stated as a general fact, that if an animal be deprived of the cerebrum and medulla oblongata, and placed under an inverted bell-glass, or otherwise protected

from external stimuli, it will not move, however easily it may be excited to motion by external impressions.

24. I must now solicit the attention of the Society to three important points: it is obvious,

25. 1st, That sensation can act, in inducing muscular motion, only through the medium of volition [1].

26. 2ndly, That, in the experiments which have been described, volition,—the *will*, and not the *power*, to move, was annihilated.

27. 3rdly, That, in such cases,—the agency of sensation being excluded, and volition destroyed,—the influence of external impressions, which might be supposed to induce pain, must have been exerted upon some property of the nervous system different from sensibility.

28. The absence of spontaneous motions in decapitated animals, proves the privation of volition; and the privation of volition removes all *evidence* of sensibility in excited motions, and indeed positively excludes its influence. Sensation, volition, and motion, may be viewed as three links of the chain, in the case in which motion is induced by pain. If the second link be destroyed, the *connexion* between the first and third is dissolved. The proof, in fine, that the excited motions which belong to the reflex function are independent of sensation, is precisely of the same character as that by which the motions due to irritability are distinguished from the same principle.

29. We are hence led to the conclusion that the excited motions of decapitated animals are dependent upon a principle different from sensation and volition; and we are further led to the inquiry—What is the nature of that principle—what the cause of those motions, which remain after sensation and volition are destroyed [2] ?

[1] See Memoir II. § 2.

[2] Ibid. § 4.

30. But before I enter upon this question, it is important to show still more distinctly than I have done, the distinction between the movements arising from the reflex function of the medulla oblongata and medulla spinalis, and those arising from irritability itself. If the glottis of an animal be touched, there is an immediate contraction. If the heart be touched, the same phenomenon is observed. What is the difference between the excited movements of these two organs? If the brain be removed, the same events still take place. If the medulla oblongata be removed, the contractions of the stimulated larynx suddenly cease, whilst those of the heart continue as before. The difference consists, then, in the presence of the medulla oblongata, which is essential to the contractions of the larynx, but of which those of the heart are entirely independent. The influence of the stimulus upon the heart is immediate. That of a stimulus applied to the larynx must pass to the medulla oblongata, and be reflected upon the part moved.

31. It is interesting to compare the excited movements of the glottis and the submaxillary textures, of the sphincter ani and the tail, and of the heart, in these several parts of the recently killed turtle, placed together upon the same table. All continue vigorous for a considerable time, until the medulla oblongata or the medulla spinalis be withdrawn, when the movements of that portion of the respiratory apparatus which is attached to the head, or of the sphincter and tail, cease in an instant.

32. The reflex function of the medulla is most permanent and apparent to observation in those animals in which the respiration is lowest. The cold-blooded animals, the hybernating animal, and the very young of the warm-blooded, are therefore the subjects in which this function can be best studied. It may be retained, or restored, however, in the adult warm-blooded animal, by retaining the respiration, or by renewing the respiration artificially,—a fact, which constitutes another characteristic of the reflex

function, and distinguishes it from irritability, and which is, in my opinion, one of the most remarkable in physiology, and highly worthy of further investigation. These remarks will readily suggest the proper choice of animals, and mode of experiment, for the display of the reflex function. I now proceed to the detail of the various experiments which I have made upon this subject, and shall then deduce the conclusions which appear to flow from them.

Sect. II. *Experiments.*

33. The phenomena of the reflex function, like those of the irritability, are, as I have just stated, more observable in the lower order of animals, in the very young of the higher orders, and in the state of hybernation. It will be found, however, that the full-grown mammalia are not less distinctly endued with this property of the nervous system, whilst the functions of respiration and circulation are continued.

34. The first experiment which I made was upon the turtle.

35. This animal was decapitated in the manner usual with cooks, by means of a knife, which divided the second or third vertebra.

36. The head being placed upon the table for observation, it was first remarked that the mouth opened and shut, and that the submaxillary integuments descended and ascended, alternately, from time to time, replacing the acts of respiration. I now touched the eye or eyelid with a probe. It was immediately closed: the other eye closed simultaneously. I then touched the nostril with the probe. The mouth was immediately opened widely, and the submaxillary membranes descended. This effect was especially induced on touching the nasal fringes situated just within the anterior part of the maxilla. I passed the probe up the trachea and touched the larynx. This was immediately followed by a forcible convulsive contrac-

tion of the muscles annexed to it. Having made and repeated these observations, I gently withdrew the medulla and brain. All the phenomena ceased from that moment! The eye, the nostril, the larynx, were stimulated, but no movement followed.

37. The next observations were made upon the other parts of the animal. The limbs, the tail, were stimulated by a pointed instrument or a lighted taper. They were immediately moved with rapidity. The sphincter was perfectly circular and closed; it was contracted still more forcibly on the application of a stimulus. The limbs and the tail possessed a certain degree of firmness or *tone*, recoiled on being drawn from their position, and moved with energy on the application of the stimulus. On withdrawing the spinal marrow gently out of its canal, all these phenomena ceased! The limbs were no longer obedient to stimuli, and became perfectly flaccid, having lost all their resilience. The sphincter lost its circular form and its contracted state, becoming lax, flaccid, and shapeless. The tail was flaccid, and unmoved on the application of stimuli.

38. This experiment affords evidence of many important facts in physiology. It proves that the presence of the medulla oblongata and spinalis is necessary to the contractile function of the eyelids, the sub-maxillary textures, the larynx, the sphincters, the limbs, the tail, on the application of stimuli to the cutaneous surfaces or mucous membranes. It proves the reflex character of this property of the medulla oblongata and spinalis. It proves that the tone of the limbs, and the contractile property of the sphincter, depend upon the same function of the medulla spinalis,—effects not hitherto suspected by physiologists.

39. I must now state that the phenomena which have been detailed subsist in distinct portions of the divided nervous system. If, after severing the head of the turtle, the lower extremities and the tail be separated together, in the manner usual with cooks, the phenomena which I have de-

scribed are still observed in the distinct and separate portions of the animal. The head, the anterior extremities, and the tail, present the movements which have been described, when severally stimulated. The posterior extremities alone were observed to be flaccid and unimpressible by stimuli and these were found, on examination, to have been separated from their connexion with the spinal marrow.

40. An interesting experiment demonstrates the powerful influence of the reflex function over the sphincter ani in the turtle. If, after the removal of the tail and the posterior extremities, with the rectum, and of course with a portion of the spinal marrow, water be forced into the intestine, by means of Read's syringe, the cloaca is fully distended before any part of the fluid escapes through the sphincter, which it then does on the use of considerable force only, and by jerks or gushes. The event is very different on withdrawing the spinal marrow: the sphincter being now relaxed, the water flows through it at once in an easy continuous stream, with the application of little force, and without inducing any distention of the cloaca.

41. I was first struck with the phenomena of the reflex function of the spinal marrow in the separated tail of an eft. On being excited by the point of a needle passed lightly over its surface, it contracted and moved as if it still formed a part of an entire animal.

42. On another occasion, having removed the head of a frog, I divided the spine between the third and fourth dorsal vertebræ, and separated the upper portion of the animal from the lower. There were then the head, the anterior extremities, and the posterior extremities, with their corresponding portions of medulla, as three distinct parts of an animal. Each preserved the reflex function. On touching an eye, it was retracted, and the eyelids closed, whilst similar phenomena were observed simultaneously in the other eye. On removing the medulla, these phenomena ceased. On pinch-

ing the toe of one of the anterior extremities, the limb and the opposite limb equally moved. On removing the spinal marrow, this phenomenon also ceased. Precisely similar effects were observed in regard to the posterior extremities.

43. Similar phenomena are also observed in the snake. If the head be removed, and a pointed instrument or a lighted taper be brought into contact with any part of the surface, it is instantly moved. The motion consists in a flexion of the entire part, and in a concentric movement of the integuments towards the point irritated; so that the muscles situated along the spine, and certain muscles analogous to the panniculus carnosus, are excited to contraction. The extremity of the tail is most impressible. The function which presides over these movements subsisted in every part of the animal separated from the rest, but instantly ceased on removing the spinal marrow.

44. On touching a point immediately within the teeth of the upper jaw, the larynx was suddenly drawn downwards and closed. These movements could also be excited by touching the nostrils. They ceased on removing the medulla oblongata.

45. Similar phenomena are seen also in the very young of the mammalia. A rabbit, one day old, was immediately deprived of all voluntary or respiratory motion, with the exception of gaspings, by dividing the spinal marrow near the occiput. Yet the head and the limbs moved, on stimulating the ears or the feet. These movements ceased in a quarter of an hour; but were renewed by artificial respiration, see § 32. The phenomena were precisely similar after decapitation, hæmorrhage being prevented and artificial respiration maintained. All ceased on removing the medulla oblongata and spinalis.

46. One of the most remarkable of the phenomena attached to the reflex function in animals, is that presented by those muscles of the hedgehog

(*Erinaceus Europæus*) by means of which that animal assumes, in certain circumstances, the form and firmness of a ball. This system seems especially to connect the roots of the spines with the muscles. If the animal be examined under the influence of hybernation, the reflex function continues for some hours after the brain is removed; the panniculus carnosus, the limbs, the tail, the larynx, the sphincter ani, remain excitable, and retain a degree of tone. These phenomena cease on removing the medulla spinalis.

47. The phenomena of the reflex function seen in the panniculus carnosus, and in other muscles of the hedgehog, are also particularly displayed in the very young animal, in which the peculiar movements of this creature are excitable for a considerable time after decapitation, or the division of the spinal marrow, and long after the cessation of the voluntary and respiratory motions, when it is in a languid and dying state.

48. In the case of the decapitated young hedgehog, after all gasping has ceased, motions of the larynx are still excited on irritating the nostrils, or on irritating the medulla itself; just as the peculiar motions of the trunk are excited on irritating the limbs, tail, or spines,—or the spinal marrow.

49. Nor are we without evidence that the same principles obtain in the human subject. The condition of the infant born without cerebrum or cerebellum, and breathing from the influence of the medulla oblongata alone, is precisely that of the reflex function, with the addition of respiration, § 9, note 1. Such a case has been witnessed and described by Mr. Lawrence [1]. "The child moved briskly at first, but remained quiet afterwards, except when the tumour was pressed, which occasioned general convulsions. It breathed naturally, and was not observed to be deficient in warmth, until its powers declined. I regret that, from a fear of alarming the mother, no attempt was made to see whether it would take the breast: a little food

[1] Medico-Chirurgical Transactions, vol. v. p. 166.

was given it by the hand. It voided urine twice in the first day, and once a day afterwards: it had three dark-coloured evacuations. The medulla spinalis was continued for about an inch above the foramen magnum, swelling out into a small bulb, which formed the soft tumour on the basis of the skull. All the nerves from the fifth to the ninth, were connected to this." This brief detail is full of interest. The respiration was natural, the medulla oblongata being entire. Swallowing was effected when food was brought into contact with the pharynx; the sphincters performed their functions; the limbs were moved when the skin was first impressed by the atmospheric air. There was no indication of sensation—the child remained quiet after the first brisk movements; and no event is mentioned which could establish the existence of voluntary motion,—the acts of swallowing, and of the expulsion of the urine and fæces, with the functions of the larynx and of the sphincters, belonging distinctly to the excito-motory system.

50. M. Lallemand has briefly described a case of anencephalous fœtus [1]. "J'ai vu, il y a quatre ans, à l'Hôtel-Dieu, un fœtus anencéphale, à terme, ou à peu près, qui vécut trois jours. Pendant tout ce temps il poussa des cris assez forts, exerça des mouvemens de succion toutes les fois qu'il sentit quelque chose entre ses lèvres; mais on fut obligé de le nourrir avec du lait et de l'eau sucrée, parce qu'aucune nourrice ne voulait lui donner le sein. Il exécutait des mouvemens assez étendus des membres thoraciques et abdominaux. Quand on plaçait un corps étranger dans ses mains, il fléchissait les doigts comme pour le saisir; mais en général tous ses mouvemens avaient moins d'énergie que ceux d'un fœtus de même âge.

51. "Le cerveaux et le cervelet manquaient entièrement: il ne restait à la base du crâne que la moëlle allongée et la protubérance annulaire, avec

[1] Observations Pathologiques, p. 86.

l'origine des nerfs pneumo-gastrique, trifacial et optique. Le tout était recouvert par les débris des os du crâne, des méninges et de la peau."

52. A similar case is detailed by M. Ollivier[1], who remarks—" J'observai l'enfant anencéphale deux heures après sa naissance. Les yeux étaient constamment fermés ; il poussait des cris fréquens qu'on calmait facilement en introduisant le petit doigt dans sa bouche : il exerçait alors des mouvemens de succion répétés ; il agitait ses membres avec assez de force, et serrait entre ses doigts les corps qu'on plaçait dans ses mains.

53. " Je le revis au bout de trois heures. Les pieds et les mains étaient devenus violets et froids ; la respiration ne s'opérait plus à des intervalles aussi rapprochés ; les mouvemens de la moëlle épinière, que j'avais remarqués d'abord, continuaient toujours d'avoir lieu, et suivaient chacune des grandes et longues inspirations qu'il faisait. Les cris étaient moins forts et moins fréquens : on lui donna à diverses reprises de petites cuillerées de vin vieux sucré.

54. "Insensiblement le refroidissement des extrémités gagna le reste des membres et le tronc ; la respiration s'opérait à de plus longs intervalles : elle devint convulsive. Cet état persista pendant six ou huit heures ; ses cris devinrent plus faibles et plus éloignés, de même que les mouvemens de la respiration, qui étaient accompagnée de convulsions générales, et il mourut dans un véritable état d'asphyxie, après avoir poussé un cri analogue à celui qui résulte du hoquet."

55. M. Ollivier adds, (p. 161)—" Il n'existait pas ici un seul rudiment de l'encéphale et des prolongemens de la moëlle alongée ; la moëlle épinière seule était restée intacte, et cependant cet infant exerçait des succions répétées, et serrait avec assez de force entre ses doigts les corps qu'on plaçait

[1] Traité de la Moëlle Epinière, ed. 2, Paris, 1827, p. 155.

dans sa main; ces mouvemens étaient loin d'être automatiques comme ceux qui agitaient les membres inférieurs."

56. These cases, in connexion with the preceding one, are full of interest. The peculiar cries, which resemble, in their rationale, the croup-like convulsion from dentition; the closed state of the eyelids; the action of suction excited by the contact of the finger; the closure of the fingers excited by objects placed in the palm of the hand, and the movements of the inferior extremities, in this acephalous infant, are phenomena of the reflex function of the most deeply interesting character.

57. The following facts are extracted from a letter addressed by Mr. Sweatman to Sir Charles Bell, and published in the "Nervous System"[1]:— In a case of parturition,—"after the membranes had given way, and the liquor amnii had escaped, the midwife on examining found another membranous bag presenting, which she naturally supposed belonged to a second child, and therefore did not interfere. During the passage of this bag under the os-pubis, it suddenly burst, and the whole of the brain escaped from the opening very much smashed, and hanging together only by its membranes. The child breathed with perfect freedom and cried strongly, rolling its eyes about in a wild, staring manner. It moved its lower extremities freely, and that not from spasm, but *obviously in obedience to external impressions*. There was no motion whatever of the upper extremities.

58. "In this state it remained for about three hours, when all motion in the extremities ceased, the eyes became fixed, and the breathing gradually slower, till it ceased altogether, just seven hours after the birth of the child. During this time neither urine nor meconium passed, nor had there been any hæmorrhage from the vessels of the brain.

59. "On examination the occipital bone and the posterior part of several

[1] Appendix, p. cxxxvi.

of the cervical vertebræ were found wanting, and their place had been occupied by fluid, surrounded by a membranous bag; an instance of spina bifida of the neck. The spinal marrow was perfect.

60. "A somewhat similar case occurred to me about three years ago, when I had occasion from peculiar circumstances to remove the brain of a child through the anterior fontanelle. In that instance, about ten minutes elapsed before its birth, yet it drew a deep inspiration, and would have cried had it not been prevented; and the motions of the *lower* extremities continued about half an hour, although the whole of the brain had been removed, and a blunt instrument repeatedly thrust down the foramen magnum [1]."

61. It is distinctly proved, by this series of observations, that the reflex function exists in the medulla independently of the brain; in the medulla oblongata independently of the medulla spinalis; and in the spinal marrow of the anterior extremities, of the posterior extremities, and of the tail, independently of that of each other of these parts, respectively.

62. There is a still more interesting and satisfactory mode of performing the experiment: it is to divide the spinal marrow between the nerves of the superior and inferior extremities. We have then two modes of animal life: the first being the assemblage of the voluntary and respiratory powers with those of the reflex function and irritability; the second, the two latter powers only: the first are those which obtain in the perfect animal, the second those which animate the fœtus. The phenomena are precisely what might have been anticipated. If the spinal marrow be now destroyed, the irritability alone remains,—all the other phenomena having ceased.

63. The spinal marrow of a frog was divided between the anterior

[1] See a similar case by Mr. Hammond, in the Medico-Chirurgical Transactions, vol. xii. p. 308.

and posterior extremities. It was immediately observed that the head and the anterior extremities alone were moved spontaneously and with design, the respiration being performed as before. But the posterior extremities were not paralyzed: they were drawn upwards, and remained perfectly motionless, indeed, unless stimulated; by the application of any stimulus they were moved with energy, but once only, and in a manner perfectly peculiar. The stimulus was not felt by the animal, because the head and anterior extremities remained motionless at the time it was applied. Nothing could be more obvious, and indeed striking, than the difference between the phenomena of the functions of sensation and volition observed in the anterior part of the animal, and those of the reflex function in the posterior: in the former there were spontaneous movements with obvious design; in the latter, movements which were the mere effect of stimulus.

64. The same experiment was made upon the toad; but for some reason, probably anatomical, it does not succeed so uniformly in this animal as in the frog [1].

65. The experiment was repeated upon a guinea-pig. The effect was an immediate and total paralysis of sensation and voluntary motion in the posterior extremities: there was no expression of pain when they were pinched, nor was there the slightest indication of a power of spontaneous motion: they were dragged along when the animal moved. But they were not unimpressible by stimuli, nor destitute of the power of moving when stimulated: on the contrary, when pinched, they displayed a sort of repeated, hurried motion, altogether peculiar. The power of the sphincters was evidently preserved. In a word, the reflex function remained entire.

66. In all these experiments the upper part of the animal presented

[1] P.S. This is fully explained by a remark on the comparative anatomy of the frog and toad in the "Systèmes Nerveux" of Desmoulins, t. i. p. 187. l. 6—15. Nothing can be more interesting than to see the anatomy and experiment illustrate each other.

the phenomena of sensation and of spontaneous movements; in the lower, there was total paralysis of these powers; yet the reflex function, the excitability, the firmness of the limbs, and the irritability remained. It now remains to be stated, that the reflex function admits of *exaltation* and of *diminution.*

67. If a frog be made to swallow a watery solution of strychnine or of opium, or if such a solution of strychnine or opium be applied to the skin, the animal soon becomes affected with symptoms perfectly similar to those of tetanus. The surface becomes highly susceptible to the impression of stimuli, and the muscles of the limbs become affected with continued spasmodic action. The affection is obviously one of augmented reflex function of the medulla. It accordingly ceases instantly on destroying the nervous masses.

68. A frog made tetanic by opium was decapitated, and divided just below the third vertebra. The eyes were retracted, and no movement could be detected on irritating the eye-lids or skin. Both the anterior and posterior extremities remained susceptible, and tetanic, as before: the limbs were moved in the same spasmodic manner by the same slight impressions. All was changed on removing the medulla oblongata and spinalis. The eyes were no longer retracted. The muscles of the limbs were immoveable under the action of stimuli, and perfectly flaccid, having lost their exalted tone.

69. Precisely similar phenomena were observed when the frog was made tetanic by opium or strychnine and divided into three portions, the head, the anterior and the posterior extremities; and in the eft made tetanic and divided into the head, anterior and posterior extremities, and tail. Each part remained tetanic, impressible by the slightest touch, and spasmodically contracted on any application of stimulus. The tetanus in each is instantaneously terminated by destroying the corresponding portion of

spinal marrow, the head, the limb, or the tail, instantly manifesting a perfectly relaxed and flaccid condition of the muscles. The irritability remains unimpaired.

70. These facts complete the proof that the phenomena which I have referred to the reflex function, do not depend either upon sensation and volition, or upon irritability. It is plain that the spasmodic actions in tetanus are not voluntary actions, and that they obey the same laws as the movements observed in an animal, or parts of an animal, not tetanic, under the influence of stimuli. It is equally plain that phenomena which depended upon excited irritability would not cease whilst that irritability remained unimpaired [1].

71. The phenomena of tetanus, in its effects upon the limbs, enable us to conceive more distinctly than we should otherwise do, the effect of the reflex function in its natural state, in maintaining the due degree of balance and antagonism of the muscles and firmness of the limbs.

72. If a few drops of dilute hydrocyanic acid be placed upon the tongue of a frog, a state of things the reverse of that just described as the effect of opium or strychnine is induced: the contractions which depend on the reflex function are observed to become less and less excitable and energetic, and at length cease altogether.

73. Having thus detailed the phenomena of the reflex function, as they are observed in their ordinary and augmented and diminished degrees

[1] Having observed these facts in connexion with the reflex function, it became a question whether the rigidity of the muscles immediately consequent to death depends upon the same principle. Two rabbits were killed; in one the spinal marrow was destroyed, in the other it was left entire. Both, however, became equally rigid. So that the spasm of death is a mere effect of irritability, and not of the reflex function of the spinal marrow.

P. S. Compare Legallois, Op. cit. p. 24; Nysten, 419; Bostock, vol. i. p. 176; Müller, Handbuch, B. II. A. I. &c.

of force, I shall briefly enumerate some of those *excited* motions observed in various parts of the animal frame, which are obviously referrible to the same function.

74. The most healthy condition of the reflex function is that, the result of which is the due state of balance between antagonist muscles. But certain excited states of this function can scarcely be viewed as otherwise than healthy: such are—winking when an object touches the eye-lid, the singular effect of dashing cold water on the face, and the singular effect of tickling upon the respiration, sneezing from irritation of the nostrils, cough from that of the larynx, vomiting from that of the pharynx, strangury from irritation of the rectum, and tenesmus from that of the bladder, &c. I can readily imagine that tickling may have been carried to such an extent as to interrupt the respiration and prove fatal by asphyxia, as in a recent instance said to have occurred on the Continent.

75. The excited reflex function is observed on touching the eye, the nasal fringes, or the larynx, in the separated head of the turtle; and on touching the sphincter, the tail, or the limbs, of the separated lower portion of that animal; in the frog, the lower extremities are sometimes moved with violence even, on the application of a stimulus, after the division of the spinal marrow. All the systems of muscles, therefore, obviously partake of this remarkable action.

76. It is plain, from the preceding observations, that the reflex function may be viewed as subsisting in its natural state, in its state of general excess or failure, and in its state of momentary and partial excitement.

III. *Pathology.*

77. There still remains an interesting part of this inquiry. What

relation does the reflex function bear to the art of physic? It will soon be seen that it throws a ray of light over some obscure points in medicine. Indeed, the study of the reflex function appears to me to reveal and explain in a manner totally new, a series of facts in pathology, and to lead to a new division of the diseases of the nervous system, coinciding with the different modes of operation of their causes, into those of *centric* and those of *eccentric* origin.

78. One of the most interesting of medical subjects, in relation to the reflex function, is that of dentition. Dentition is a sort of natural experiment upon this function. The general convulsion, the strabismus, the spasm of the fingers and toes, the croup-like affection of the respiration, the repeated vomitings, the tenesmus, the strangury, the involuntary discharge of urine and of the fæces, from its operation, denote the influence of irritation of the maxillary nerves, through the medium of the medulla, upon the muscles of voluntary and respiratory motion, of the eye, the larynx, the sphincters, &c., in the human subject, and indicate so many arcs of the reflex function. However these *facts* may have been known, their true *rationale* has not been discovered. In all such cases the remedy is, to relieve the part in which the cause is operating. In the present instance the maxillary nerves and vessels are to be relieved by free scarification; the lancet should be used freely, daily, or still more frequently.

79. The young of other animals, and especially of the feline and canine species, are exceedingly subject to similar effects from dentition, which are not unfrequently fatal. The fatal event is frequently owing to interrupted respiration. In one instance, the asphyxia was averted, in a very young puppy, by artificial respiration, effected by alternate compression and relaxation of the parietes of the thorax.

80. The reflex function is far most excitable in the very young animal.

The second dentition rarely, therefore, induces such affections as the first; and epilepsy is much rarer in adults than convulsions in infancy.

81. With the effects of dentition in infants, some affections of the adult may be compared, as chorea, some forms of epilepsy, and some forms of asthma. The diseases to which these designations have been given vary exceedingly in different instances: inasmuch as some cases are of centric and others of eccentric origin. One characteristic distinguishes the latter form of the disease,—it usually combines more affections of the reflex function than one. Such a form of epilepsy, for example, combines hickup, or even vomiting, with the epileptic attack. The usual source of those forms of disease is in the intestinal canal, the stomach being irritated by improper diet or the bowels by morbid contents. This division of the subject leads to an important distinction of these cases into those which admit comparatively more easily, and more difficultly, of cure.

82. Epilepsy is plainly of two kinds: the first has a centric origin in the medulla itself: the second is an affection of the reflex function, the exciting cause being eccentric, and acting chiefly upon the nerves of the stomach or intestines, which consequently form the first part of the reflex arc. The fact of the frequent occurrence of a fit of epilepsy in coitu is very interesting in reference to the reflex function: it distinctly connects these two events; and it affords another instance of an influence exerted, through the medium of this function, between distant parts of the spinal marrow. There is but a step, as it were, from the normal affection of the nervous, muscular, and respiratory systems, in that circumstance, to an attack of epilepsy itself;" Hippocratis verba hoc traduntur; *την συνουσιαν ειναι μικραν επιλημψιαν.*

83. The disease termed asthma claims rather more than an incidental notice in this place. True asthma, viz. that form of this disease which

occurs in youth, and assumes a distinctly spasmodic form and course, like so many other morbid conditions of the reflex function, frequently arises from gastric or intestinal irritation. It is also frequently excited by the contact of certain powders, as that of ipecacuanha, with the larynx, just as sneezing is induced by similar impressions upon the nostrils. It appears to consist in an action excited, through the reflex function, in the larger bronchia. The influence of the smoke of the stramonium in relieving the attack of asthma is another argument in favour of its being an affection of the reflex function. Indeed, a comparison of the various causes, the mode of attack, course, and the effects of remedies, in this singular morbid affection, alike denote its relation to this peculiar function.

84. With the effects of dentition, those of gastric or enteric irritation, in their multiplied forms, may be compared.

85. Tenesmus and strangury are affections of other arcs of the reflex function.

86. One circumstance in the pathology of the reflex function is very remarkable. Several forms of the morbid affections of this function occur during the first sleep. This is the case with the croup-like affection arising from dentition, with spasmodic asthma, and with a peculiar painful affection of the rectum, not hitherto described.

87. Tetanus and hydrophobia appear equally to result from injuries inflicted upon the extremities of certain nerves, by means of which the morbid influence is conveyed to the medulla, whence it is reflected through the motor nerves to the muscular system. As free lancing of the gums in dentition, so the early division of the wounded nerve or amputation in tetanus, has, at once, checked the morbid affection. Is it possible that hydrophobia might be arrested by a similar procedure? The subject is of intense interest, and deserving of the fullest attention.

88. Certain poisons, as the strychnine, induce excess in the reflex

function; other poisons, as the hydrocyanic acid, destroy it altogether. In both cases the muscular irritability remains perfect and undiminished. It is probably through the medium of the same functions that some other poisons act upon the animal economy.

89. In a frog, recently killed by strychnine, the irritability of the muscular fibre remained unimpaired,—a proof that the tetanus of strychnine is an exalted condition of the reflex function, and that the consequence is the exhaustion of that function, and not of the irritability. Another frog, destroyed by the hydrocyanic acid, presented similar phenomena of unimpaired irritability on the application of galvanism. In either case, if the animal be placed in water through which a slight galvanic shock is passed, the limbs are immediately and forcibly extended.

90. The study of the reflex function will doubtless throw an important light upon toxicology, as well as some parts of pathology, and of the causes and treatment of diseases,—subjects which, as they are more immediately connected with medicine, I purpose forthwith to pursue elsewhere.

91. Diseases of the nervous system, then, may be divided into those which have their origin at the nervous centres, and those which originate at a distance from those centres; and especially in some part of the nervous arc, the function of which has formed the subject of this paper,—into those of *centric* and into those of *eccentric* origin. It is highly probable that the diseases of the latter class are more numerous than they may at first be supposed to be. Chorea, hysteria, tremor, and convulsion have, doubtless, sometimes a centric, sometimes an eccentric origin. In the latter case, the nervous centres may become morbidly affected in the course of the disease, and the appearances after death may mislead the medical inquirer as to the original cause and seat of the disease. But the whole of this investigation must be reserved for the Transactions of another Society. I shall add but one fact more of a medical character in this place.

92. Legallois appears to have experienced great difficulty in explaining the occurrence of paralysis from disease of the cerebrum, impressed, as he was, that the spinal marrow constituted the source of voluntary motion. He observes, "Quand bien même on n'apercevrait aucun moyen de les concilier, il n'en demeurerait pas moins vrai, d'une part, qu'une affection bornée uniquement au cerveau peut ôter le sentiment et le mouvement volontaire à la moitié du corps, et de l'autre, que le sentiment et le mouvement volontaire peuvent subsister et être entretenus dans un animal décapité. Quelque opposés que ces faits paraissent être, il faut se souvenir que deux faits bien constatés ne peuvent jamais s'exclure l'un l'autre, et que la contradiction qu'on croit y remarquer tient à ce qu'il y a entre eux quelque intermédiaire, quelque point de contact qui nous échappe [1]." The facts which have been detailed in this paper enable us readily to remove this difficulty, and to account for the paralysis induced by disease of the cerebrum, on one hand, and for the movements of an anencephalous fœtus in utero, or of a decapitated animal, on the other. The paralysis consists in the loss of voluntary motion; the movements of the anencephalous fœtus result from the agency of the reflex function of the medulla spinalis. Legallois' error was that of mistaking the phenomena of the reflex function for sensation and voluntary motion; and his difficulty naturally arose out of this error. There is no real discrepancy between the two orders of facts to which Legallois refers. The "intermédiaire" is made obvious in this Memoir.

93. The same facts enable us to understand how a perfect action of the sphincters is compatible with paralysis of the limbs from disease of the cerebrum, and even of the higher parts of the medulla spinalis; whilst paralysis of the sphincters is usually conjoined with paralysis of the limbs, arising from disease of the lower part of the spinal marrow. The first in-

[1] Op. cit. p. 21.

tercept the principle of voluntary motion; the second affects the very seat of the reflex function which presides over the action of the sphincters.

IV. *Inferences.*

94. I shall now briefly enumerate the inferences which flow from the preceding facts and experiments.

95. Physiologists have hitherto enumerated only *three* sources or principles of muscular action,—volition, the motive influence of respiration, and irritability.

96. There is, however, a *fourth* source of muscular motion distinct from any of these, though not hitherto distinguished, to which I have ventured to give the designation of *the reflex function of the spinal marrow.*

97. Volition and the motive influence of respiration are direct in their course, and spontaneous in their action; the former proceeding from the cerebrum, the latter from the medulla oblongata [1].

[1] M. Flourens seems clearly to have determined that sensation and volition are seated in the cerebrum. Legallois (Œuvres, p. 17.) and he have ascertained that one office of the cerebellum is to regulate the voluntary motions. Legallois and Sir Charles Bell have shown that the medulla oblongata [2] is the source of the respiratory motions. It is now, for the first time, I believe, shown that a peculiar function of the medulla, superadded to its functions as a mere nervous chord, is that of imparting a state of equilibrium to the muscular system, independently of the influence of the organs which originate and regulate the voluntary and respiratory motions. These several functions are separated, and, in a certain degree, isolated by removing the cerebrum, the cerebellum, and the medulla oblongata in succession; the last stage of the experiment leaves the reflex function alone,—a function which supplies the deficiency left by the investigations of Legallois, M. Flourens, and Sir Charles Bell, and constitutes the complement of the functions of the nervous system.

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[2] This discovery of Legallois is amongst the most brilliant in physiology, and obviously presents the outlines of that, still more splendid, of the system of the respiratory nerves by Sir Charles Bell. (Œuvres, pp. 66, &c. The Nervous System, pp. 131; 145—8; 222; cxxv; &c.

P. S. The medulla oblongata is not, however, the *source* of respiration, but the channel through which the *centres* act. See § 9. and Memoir II. § 168.

98. The movements of irritability are the result of the immediate application of a stimulus to the nervo-muscular fibre itself.

99. The reflex function is different from any of these:

100. It remains attached to the medulla spinalis, when the cerebrum and the medulla oblongata are removed: it is not direct like volition, or the motive power of respiration.

101. Its seat is the medulla generally: it ceases when the medulla is removed, leaving the irritability entire: it is not excited immediately, like the movements of irritability, but mediately, in a reflex course, through the medulla, from the part stimulated to the part moved.

102. In a state of health, the reflex function presides over the orifices and terminations of the internal canals, such as the glottis and the sphincters, preserving the former open, the latter closed: and it maintains the due tone of each muscle, and the due equilibrium of each system of muscles.

103. When excited, it gives origin to the movements observed in deglutition, or vomiting, sneezing, tenesmus, &c. The fingers passed into the *pharynx* of a dog, through an incision made between the thyroid cartilage and the os hyoides, excites the act of deglutition[1]; passed over the root of the tongue to the *fauces*, it excites the associated actions of the muscles of the larynx and of expiration[2], which constitute the act of vomiting.

104. When morbidly augmented, it constitutes certain forms of disease, as tetanus, hydrophobia, certain forms of tremor, paralysis agitans, chorea, stammering, &c.; when diminished, it induces those forms of tremor observed when the vital powers are enfeebled.

[1] De l'Usage de l'Epiglotte, p. 3.

[2] See a Memoir by the author on the Mechanism of the Act of Vomiting, in the Journal of the Royal Institution, 1826, Part I. (April to June), p. 388.

105. When otherwise morbid, it occasions other forms of disease, as the convulsion, the croup-like respiration, the affection of the sphincters, observed in dentition, the various effects of intestinal irritation, &c.

106. The effects of the excited reflex function are sometimes observed in a part *near* that irritated, as in the eye-lids in winking, in the glottis on inhaling a drop of water or particle of food, in the sphincter ani in dysentery, &c.; sometimes in parts *remote*, as in the irritation of teething when this induces strabismus, convulsion, the croup-like respiration, relaxed sphincters, &c.

107. However some of the facts detailed in this paper may have been previously known,—and many were so known [1],—they have never been accurately distinguished from sensation and volition,—functions of the *cerebrum*,—and associated with a peculiar reflex function of the medulla oblongata and medulla spinalis, influencing other organs besides the limbs, and constituting the principle of tone and of a particular series of actions. It has long been known, for example, that the limbs of a decapitated animal moved on being stimulated; but the phenomenon was confounded with sensation and voluntary motion [2]. It has long been known that carbonic acid could not be inhaled through the larynx; but it has not been shown that this phenomenon depends upon the presiding agency of the medulla oblongata; nor has it been distinctly demonstrated that the functions of the sphincter ani, by which the intestinal excretions are retained for a time, is constantly dependent upon a similar agency of the lower part of the medulla spinalis. In like manner, the *facts* relative to the irritability were altogether known to Harvey and other physiologists long before Glisson and Haller finally separated this principle of motion from sensation and volition, with which, like the reflex function, it had previously been

[1] Compare Whytt, Legallois, Mayo, &c.

[2] Legallois, &c.

confounded. Yet who pretends to deprive these authors of the merit and honour of having first pointed out a distinct principle of muscular action?

108. An interesting parallel might, indeed, be instituted between the principle of the reflex function and that of the irritability, in regard to their history and degree of importance: their history is the same; for both had been confounded with sensation and voluntary motion [1]: their importance is precisely the same; for each presides over its own distinct order of functions.

109. Legallois plainly mistook the reflex function of the medulla for the principle of sensation and voluntary motion; and no physiologist has distinguished its agency, in the function of the larynx and of the sphincters, from the influence of the brain, or from irritability. The view of M. Cruveilhier, that the medulla spinalis is a mere nervous chord, is at variance with all the facts and experiments detailed in the course of this paper.

110. It is obviously from the mistake which has been pointed out, that Legallois experienced the difficulty expressed in the following words: "Comment se fait-il qu'après la décapitation, les seuls mouvemens inspiratoires soient anéantis et que les autres subsistent? C'est là, à mon sens, un des grands mystères des puissances nerveuses, mystère qui sera dévoilé tôt ou tard, et dont la découverte jettera la plus vive lumière sur le mécanisme des fonctions de cette merveilleuse puissance [2]." It was impossible to explain this difficulty whilst the movements of the excited reflex function were confounded with those of voluntary motion: but when this distinction is duly made, nothing is more easy. Decapitation removes, in fact, the sources both of voluntary and of respiratory motion; both these kinds of motion consequently cease: but a class of motions still remains,

[1] Compare Whytt and Legallois.

[2] Œuvres, pp. 63, 64.

viz. those of the reflex function, attached to the remaining portion of medulla. Thus is the veil raised from this apparent "mystery."

111. As Legallois has confounded the reflex function with the sensibility and voluntary motions, M. Brachet [1] has confounded it with the functions of the ganglionic system, or the sympathetic. The latter physiologist concludes, that whatever function remains after the division of the spinal marrow, in the organs below that division, must be referrible to the influence of the ganglionic system. In this manner he attempts to prove that some parts of the act and function of generation, in both sexes, besides the secretions, depend upon this influence; whereas it is certain that they depend upon the lower portion of the medulla spinalis, and belong to the reflex function. It is obvious, that, whilst the secretions may depend on the ganglionic system, the act of excretion, and especially the action of the ejaculatory muscles, is an excited act of the reflex function, which has been fully proved to subsist in every portion of the divided medulla spinalis. This view of the subject is greatly confirmed by a comparison of the act alluded to, with that of deglutition (§ 640, note), and others demonstrably belonging to the reflex function. We know that some reptiles remain in coitu after the head is removed. This is then an act of the reflex function alone. It may take place without sensation, as in cases of disease of the medulla spinalis.

112. I may state, in conclusion, that all the functions of the muscular system which remain after the sources of the motive influence of the voluntary and respiratory motions are removed, with the exception of those of the heart, and other muscles which contract upon the principle of excited irritability, depend upon the reflex function.

113. The principles of the movements in the animal economy, viewed

[1] Du Système Nerveux Ganglionaire, p. 246, &c.

in an anatomical and functional point of light, may now be enumerated thus:

114. 1. The cerebrum, or the source of the voluntary motions.

115. 2. The medulla oblongata, or the source of the respiratory motions [1].

116. 3. The medulla spinalis generally, the middle arc of the reflex function.

117. 4. The muscular fibre, or the seat of the irritability.

118. 5. The sympathetic, or the source of nutrition, of the secretions, &c.

119. It is not pretended that this arrangement is either strictly accurate or complete. These principles of action are, besides, frequently and variously combined, and much ulterior investigation is required to ascertain the share and fix the limit of each in various compound operations of the animal economy.

120. The reflex function of the different portions of the medulla presides over their corresponding organs: that of the medulla oblongata presides over the larynx and the pharynx; that of the lumbar and sacral portion of the medulla spinalis presides over the sphincter ani, the cervix vesicæ; the intervening portions of the medulla give tone and equilibrium to the corresponding portions of the muscular system, and what Legallois has so vaguely designated "*life*," to the corresponding regions of the body. But the operation of the reflex function is by no means confined to parts corresponding to distinct portions of the medulla. The irritation of a given part may, on the contrary, induce contraction in a part very remote: the irritation of teething may induce spasmodic action or relaxation of the sphincters: the irritation of the nostrils, in the case of a young hedgehog, when so languid that voluntary motion and respiration had ceased, induced as energetic con-

[1] See Memoir II.

traction of the most distant part of the panniculus carnosus and of the muscles of the posterior extremities, as irritation of the posterior extremities or tail themselves.

121. It would seem, from what I have observed in the young of the hedgehog and of other animals, when languid, torpid, or *dying*, that the voluntary motions cease first, then the respiratory motions, next those of the excited reflex function, and, lastly, those of the irritability; the last act of the irritability being that which induces the cadaveric rigidity. After all evidence of irritability has ceased, it is probable that the functions of the sympathetic may still continue.

122. Such is the order, then, in which this series of functions disappears in death; an order which is inverted when the same functions and their appropriate organs gradually came into existence, in the fœtal and natal states, and in the progressive series of the animal kingdom. The movements of the fœtus in utero are entirely phenomena of the reflex function: they occur in the anencephalous as well as in the perfect fœtus [1]. This function and the irritability constitute, indeed, the principles of life and motion in the *fœtal state*.

123. The functions, in *sleep*, seem to be diminished, and that in the same order. This is particularly seen in the deep lethargy of the hedgehog. The animal becomes quiescent; then it nearly ceases to respire; then the action of the panniculus carnosus yields to partial relaxation; lastly, the heart beats with a reptile slowness. In ordinary sleep, the muscles which retain the eye open lose their powers, and the eye-lids close by an act of the reflex function, just as they are kept closed in the anencephalous infant. The eye is only partially closed, even during sleep, in cases of extreme languor and exhaustion, with diminished energy of the reflex function.

[1] See M. Lallemand's Observations Pathologiques, p. 68.

Volition is first impaired, and the eye-lids close; the reflex function next fails, and the eye-lids close partially only.

124. It appears probable that the facts of this paper may lead to some important additions to our knowledge of anatomy, by inducing an accurate inquiry into the origin, course, connexion, and distribution of the subcutaneous, or submucous, and muscular nerves, which constitute the arcs of the reflex function. There can be no doubt that a system of nerves takes its origin from the lower portion of the spinal marrow, to supply the sphincters and the organs of generation, which may be compared to those which concentre in the medulla oblongata. The medulla is also, in its whole course, the source of nerves which supply the limbs, the tail, and the panniculus carnosus, in those animals which possess these structures respectively.

125. It was observed in one frog that the strychnine applied to a single posterior extremity induced general tetanus. General tetanus, in the human subject, is the effect of the local wound of a nerve. These facts demonstrate the strict connexion and unity of the different parts of the nervous system.

126. The anatomy of the reflex function must be particularly studied in the medulla oblongata; in the portions of the spinal marrow which give origin to the nerves of the anterior and posterior extremities; in that of the intermediate space which supplies the trunk; in that which is the source of the nerves of the sphincters, the ejaculators, &c., and in that which supplies the tail; and, lastly, in reference to the several columns of which the spinal marrow is composed. I think the investigation of the anatomy will, for various reasons, be best pursued in the hedgehog.

127. It is gratifying to me to state that no part of these experiments has inflicted pain, beyond that of prompt decapitation, or division of the spinal marrow. This is true, at least, if the conclusion be correct, that

when the head is removed from the body, sensation and volition cease, whilst the reflex function and the irritability alone continue; and it may be satisfactory to the humane to know that the motions of the eel, for example, after the head is removed, are not motions arising from sensibility, but from another principle, as distinct from feeling as the irritability of the mere nervo-muscular fibre. This fact will suggest the propriety, as well as the means, of avoiding such monstrous cruelty as that of skinning eels alive. This will be effectually done by first removing the head, however the animal may afterwards move on the application of stimuli, and *appear to feel*.

V. *Recapitulation.*

128. To avoid misapprehension, I think it right, in conclusion, very briefly to recapitulate the claims of this paper:

129. 1. Many of the facts which depend upon the reflex function have long been known to physiologists:

130. 2. But these facts only extend to the excited action of the reflex function, seen in the limbs, and even they have been erroneously ascribed to sensation and volition, or instinct:

131. 3. The facts of excited movements of the larynx, pharynx, sphincters, and ejaculators, and of the panniculus carnosus, have not been shown to be allied to these, and to be dependent on the same individual function of the nervous system:

132. 4. It has not been shown that this function, in its natural state, constitutes the principle of equilibrium and tone, in the whole muscular system, and the principle which presides over the orifices and sphincters of the internal canals:

133. 5. And certainly not, that this principle, morbidly affected, constitutes, in its different forms, the diseases arising from dentition, and the

diseases termed tetanus, hydrophobia, chorea, paralysis agitans, certain forms of epilepsy, of tremor, of asthma, &c. &c. :

134. 6. Nor that the same individual function is augmented or diminished to a fatal degree, by certain poisons.

135. 7. This series of facts has not been duly associated and shown to belong to *one* particular *order :*

136. 8. The principle of action in this order of facts has not been demonstrated to be at once excited, and reflex, in its operations, to be essentially connected with corresponding portions of the medulla oblongata and medulla spinalis, and to be independent of the brain :

137. 9. Nor has it been clearly distinguished from the other sources and principles of muscular motion existing in the animal economy, viz. volition, the motive influence of respiration, and irritability, or shown to constitute, with the irritability, the principle of life in the fœtal state :

138. 10. The reflex function appears, in a word, to be the *complement* of the functions of the nervous system hitherto known.

139. I trust it will be found, from this brief recapitulation, that the foregoing paper may have done some little service to physiological science. I consider the subject as but sketched,—the investigation as but just begun. One part of this inquiry is altogether untouched,—the influence of the mind and emotions, and the corresponding parts of the nervous system, upon the organs which are the subjects of the reflex function. The muscles of the voluntary and respiratory motion are alike under the influence of the reflex function ; and the muscles over which this function more peculiarly presides are impressible through volition and respiration : other muscles, which are especially attached to the reflex function of the lower portion of the medulla spinalis (p. 30), are apparently under the

influence of the cerebellum [1]. Mental emotions modify the reflex function: they induce sickness, relax the sphincters: they also aggravate the diseases of this function, inducing the attacks of epilepsy, of the croup-like convulsion, &c.

[1] See Serres, Anatomie Comparée du Cerveau, tome ii. p. 601, &c.

MEMOIR II.

ON THE

TRUE SPINAL MARROW,

AND THE

EXCITO-MOTORY SYSTEM OF NERVES.

ON THE

TRUE SPINAL MARROW,

AND THE

EXCITO-MOTORY SYSTEM OF NERVES[1].

SECT. I.—*General Laws of the Excito-Motory Property.*

1. MY OBJECT in the following Memoir, is the development of a great principle in physiology,—that of the special function, the physiological, pathological, and therapeutic actions and relations, of the true spinal marrow and of a system of excito-motory nerves.

2. It is this principle which operates in all those actions which have been designated sympathetic, which regulates the functions of ingestion and expulsion in the animal œconomy, and which guards the orifices and sphincters of the animal frame.

3. The principle to which I allude, has been confounded with sensation, and voluntary, and what has been designated instinctive, motion, by *all* physiologists, with one[2] single exception. It has been supposed to be a function of the rational[3], or irrational[4], soul. It has been considered by

[1] *Read before the* ROYAL SOCIETY *on February the* 16*th and* 23*rd, and March the* 2*nd,* 1837.

[2] Sir Gilbert Blane, Bart. See the Phil. Trans. for 1788; and Select Dissertations, p. 262.

[3] Stahl.

[4] Whytt. See § 48.

some [1], as attached to the brain; by others [2] as attached to the brain and spinal marrow; by others [3] as peculiarly attached to segments of the spinal marrow; it has been viewed by others as the function of the sympathetic [4], or of the pneumogastric [5] nerve; and lastly, by others as operating through identity of origin [6], or anastomoses [7], of nerves. It will be readily admitted, from this discrepancy of opinion merely, that the subject was involved in great obscurity.

4. I believe that my investigations have not only confirmed the opinion stated in my former Memoir [8],—that the phenomena in question do not depend upon sensation,—but have demonstrated that they depend upon a distinct principle of nervous action, long very partially known to physiologists, but altogether unapplied to the explanation of the phenomena of life. This principle is that termed *vis nervosa* by Haller, *motorische kraft* or *vis motoria* by Prof. Müller, and *excitabilité* by M. Flourens.

5. It was ascertained that the vis nervosa subsists in the tubercula quadrigemina [9], the spinal marrow [10], and the motor nerves, to the exclusion of the brain and the nerves of sense [11],—the olfactory, the optic, the acoustic,—and in the anterior [12], to the exclusion of the posterior, roots of the spinal nerves.

6. It has been supposed by all physiologists that this vis nervosa acts *only* in the direction of the nervous branches, or fibres, *from* their source in the nervous centres *to* their destination in the muscular system. Haller

[1] Haller, &c. [2] Whytt; Sœmmering; Dr. Alison; Prof. Müller, &c.
[3] Legallois; M. Flourens; Mr. Mayo, &c. [4] Tiedemann; Lobstein.
[5] Sir Charles Bell; Shaw. [6] Mr. Mayo, &c. [7] Willis; Shaw.
[8] See the Phil. Trans. for 1833; and Memoir I. [9] M. Flourens.
[10] Lorry; M. Flourens, &c. [11] M. Magendie.
[12] Such was the deduction from Prof. Müller's experiments on the *frog*. I have found that it is not correct in reference to the *turtle* and the *skate* (*Raia batis*): galvanism applied to the posterior or the anterior roots equally induced muscular action.

observes, "Irritato nervo, convulsio in musculo oritur, qui ab eo nervo ramos habet. Irritato vero nervo, multis musculis communi, totive artui, omnes ii musculi convelluntur, qui ab eo nervo nervos habent, sub sede irritationis ortos. Denique medulla spinali irritata, omnes artus convelluntur, qui *infra* eam sedem nervos accipiunt; *neque* contra artus, qui *supra* sedem irritationis ponuntur." Haller concludes, "Conditio illa in nervo, quæ motum in musculis ciet, *desuper* advenit, sive a cerebro et medulla spinali, *deorsum*, versus extremos nervorum fines propagatur." And, "Ut adpareat causam motus a trunco nervi in ramos, non a ramis in truncum venire[1]." Prof. Müller treats this subject still more at length, and has laid down the following laws in regard to the mode of action of the motor power:—

7. "1. The motor power acts *only* in the direction of the primitive nervous fibres going to muscles, or in the direction of the branches of the nerves; and *never backwards*.

8. "2. The mechanical or galvanic irritation of a part of a nervous trunk does not excite the motor power of the whole nerve, but only of the isolated part.

9. "3. A spinal nerve which passes into a plexus, and assists, with other spinal nerves, in the formation of a large nervous trunk, does not impart its motor power to the whole of that trunk, but only to the fibres which it affords in its course from that trunk to the branches.

10. "4. All nervous fibres act in an isolated manner from the trunk of a nerve to its ultimate branches[2]."

11. Thus, if a muscular nerve or nervous fibre be stimulated, either mechanically by the forceps, or by means of the galvanic influence passed

[1] Elementa Physiologiæ, Lausannæ, t. iv. p. 325.

[2] Handbuch der Physiologie, i. 656.

across its fibres, the muscle or muscles to which it is distributed are excited into contraction. This fact is represented in Plate I., Plan I., Fig. 1.

12. The same phenomenon is observed, if, instead of stimulating a muscular nerve, the spinal marrow itself be subjected to the action of a mechanical or the galvanic stimulus. All the limbs, the muscles of which receive nerves from *below* the part of the spinal marrow which is subjected to the influence of the stimulus, are thrown into action. This fact is represented by Plate I., Plan I., Fig. 2.

13. These two facts are amongst the oldest in physiology. They have one application to the explanation of the natural functions, in the instance of the *tone* of the muscular system. They also explain some of the symptoms in the centric diseases of the spinal marrow, and in the diseases of motor nerves.

14. It has been ascertained by M. Flourens[1], that this power of exciting muscular contraction is limited to the tubercula quadrigemina, the medulla oblongata, the medulla spinalis, and the muscular nerves; and it is supposed by Prof. Müller[2] to be limited in the frog to the anterior or motor, to the exclusion of the posterior or sentient nerves[3].

15. Such was the state of our knowledge on this important principle of muscular action in the spinal marrow and motor nerves, when I began a series of experiments on the rabbit, the turtle, the frog[4], the lobster, (*Astacus marinus*) &c., which have disclosed a series of phenomena equally novel and important, directly at variance with the conclusions of Haller, and the first of the laws proposed by Prof. Müller, and of the most extensive application to physiological, pathological, and therapeutic phenomena.

16. I first discovered that the motor power in *the spinal marrow* will

[1] Du Système Nerveux, p. 21.
[2] Handbuch der Physiologie, i.625.
[3] See § 5, note 12.
[4] See Memoir I. § 15. 23.

act in a *retrograde* direction: this fact is represented Plate I., Plan II., Fig. 1.

17. I ascertained, in the second place, that this power acts in a retrograde direction, not in the spinal marrow only, but in *nerves* connected with the spinal marrow. Its agency is then *incident* along nerves proceeding into the spinal marrow, both *direct* and *retrograde* along the spinal marrow itself, and *reflected* along nerves proceeding from the spinal marrow. These facts are represented Plate I., Plan II., Fig. 3.

18. In these two instances I observed that the agency of the motor power was very different from that sometimes observed when a nerve or the spinal marrow is stimulated, and its *direct* effect alone is observed. The movements were more gradual and uniform, and less partial and sudden, obviously resulting from an agency of a more *combined* character.

19. That these actions are identical in their nature with those produced in the experiments of the older physiologists upon the vis nervosa, was made obvious by an experiment in which I produced *both* effects, by the same individual application of a stimulus. On irritating the middle portion of the spinal marrow, by the forceps, or galvanism, I excited simultaneous movements of both posterior and anterior extremities. This fact is represented in Plate I., Plan II., Fig. 2.

20. It remained for me to show that the retrograde and reflex movements which I have described as resulting from a stimulus applied to an incident nerve, are the same as those induced by a stimulus applied to a cutaneous or mucous surface. I irritated the *skin* in various parts of the turtle,—the trunk, the limbs, &c., and I produced movements of the extremities precisely similar to those which I have described as arising from the irritation of an incident nerve. This fact is represented Plate I., Plan II., Fig. 4. I may here recall to mind the closure of the eyelids—of the eyelids of both eyes—on touching the border of the eyelid; and the firmer

closure of the sphincter, on touching the border of the anus; experiments which I performed upon the turtle several years ago [1].

21. After this experiment, it is natural to recall another, similar in every respect, except that instead of a *cutaneous* surface, a *mucous* surface is irritated. On touching the border of the glottis, in animals in which it is naturally open, the larynx closes; on passing the finger into the pharynx, it contracts. Indeed it frequently happens that the termination of a nerve is excito-motory although the trunk is apparently not so.

22. A step further, and we come to the excited acts of respiration, on dashing cold water on the face, or general surface of the body,—in man; on irritating the nostril, the palatine fringes, the internal larynx in the turtle; &c.

23. It was next necessary to show that these actions were *excited*, and ultimately *accomplished*, through the medium of appropriate incident and reflex *nerves*, and their connecting medium the spinal marrow. I therefore devised a series of experiments represented, Plate I., Plan III.

24. Figures 1 and 2, Plate I., Plan III., represent the course of incident nerves—as the trifacial, the spinal centre, and the course of reflex nerves—as the facial, through which the excito-motory property acts. It is essential that the nervous connections throughout this incident, central, and reflex course be preserved entire. (Plan III., Fig. 1.) If any part be interrupted, the phenomenon ceases instantly. Fig. 3 and 4, represent the spinal centre destroyed; Fig. 5 represents the experiment in which the incident nerve alone; and Fig. 6, that in which the reflex nerve alone; and Fig. 7, that in which both are severed. In *all* these cases the phenomenon ceases instantly and entirely.

25. These facts prove that certain incident nerves, as well as the

[1] See Memoir I. § 36. 37.

spinal marrow and motor nerves, are excito-motory; and they establish a *Class* of such nerves previously unknown to physiologists, or confounded with sentient nerves.

26. A further series of deductions, flowing from these facts, is represented in Plate I., Plan IV., Fig. 1, 2, 3, 4.

27. Fig. 1 and 2 represent an incident nerve, as the trifacial, or the nerve which supplies the border of the larynx, or of the sphincter ani, proceeding to the upper or lower portion of the spinal marrow, and a reflex nerve, as the facial, the pneumogastric, or the nerve of the sphincter ani, proceeding from that organ, to and from points which are nearly on the same parallel.

28. Fig. 3 and 4 denote the former the *direct*, the latter the *retrograde* course of the excito-motory influence along the spinal marrow, as observed in experiments in physiology, and in the effects of diseases and of remedies, and disprove the idea of the excito-motor phenomena being restricted to *segments*[1] of the spinal marrow.

29. From these deductions from my experiments we may further infer the existence—

30. 1. Of a *True Spinal Marrow*, *physiologically* distinct from the chord of intra-spinal nerves;

31. 2. Of a *System of Excito-Motory Nerves*, *physiologically* distinct from that of the sentient and voluntary nerves;

32. 3. Of a nervous influence—the excito-motory power—operating in directions *incident*, *upwards*, *downwards*, and *reflex*, with regard to the true spinal marrow, the centre of this excito-motory system.

33. The entire medulla spinalis in the *Vertebrata* consists then of *two* portions, so intimately blended together, indeed, as not to be easily separated by the anatomist, and, perhaps, only to be distinguished by

[1] See Mr. Mayo's Outlines of Physiology, Ed. 4. p. 213, &c.

physiological experiment and pathological observations. The *first* of these, is the intra-vertebral *chord* of sentient and voluntary *nerves*, which proceed *to* and *from* the *cerebrum* as their centre. It is represented Plate III. Fig. 1. The *second*, which may be denominated the true spinal medulla, is distinguished by being *excito-motory*, and is the axis of a peculiar system of excitor and motor, or excito-motory, nerves, generally, but perhaps not invariably, blended with the former. This is represented Plate III. Fig. 2.

34. The close combination of these two portions of the nervous system, in the *Vertebrata*, is the consequence of the necessity for the several pairs of compound nerves being *inter-vertebral* in their exit from the spinal canal. In the *Articulata* this necessity does not exist, and the two systems may, therefore, be anatomically, as well as physiologically, distinct. Indeed, I think I have ascertained that, whilst the ganglionic nerves in the lobster are incident and excitor, and the columns both direct and retrograde in their influence, the aganglionic nerves are purely motor, as Prof. Grant first conjectured, and direct in their mode of action.

35. These observations lead naturally to the question,—Is there, in any class of animals, a distinct *Anatomy* of the excito-motory power? Are there excitor nerves distinct from nerves of sensation? Are there motor nerves distinct from nerves of volition?

36. In the first place, I may observe that the olfactory, optic, and acoustic nerves, are nerves of *sense* only, and destitute of excito-motory power. So are the cerebrum and cerebellum, the former of which is probably the centre of the sentient and voluntary system. Is there a pure *voluntary* nerve?—a nerve which conveys the acts of the will, without possessing the motor or excito-motory power? It appears to me, that *one* such purely voluntary nerve only exists; for every muscle of the animal frame, with one exception, seems to require *tone*, which is a result of the excito-

motory power, conveyed by motor nerves, probably involved, in general, in the same neurilemma with voluntary nerves. This power acts during *sleep*,—in *all* muscles, *except the levator palpebræ*, and perhaps the four *recti* oculi.

37. But as there are purely sentient nerves, it may be a question, whether there be purely excitor nerves. Such a nerve probably does not exist absolutely in health. An experiment made by Mr. Broughton, Mr. Field, and myself, in 1835, led to the conclusion that the *pneumogastric* nerve is destitute of sentient property. This nerve is certainly the least sentient, and the most purely excitor, of any in the class *Vertebrata*. In certain cases of disease, we, however, observe the sentient power annihilated, whilst the excito-motory still continues: this occurs in those diseases of the brain which destroy the sensibility of the face; the excito-motory properly may remain, and the eyelash and the nostril be as susceptible of stimuli as ever. In the experiments in which the cerebrum, the *centre* of the sentient and voluntary system is removed, and in diseases and in other experiments in which the spinal marrow is disorganized or divided, the phenomena which remain are entirely of the excito-motory class. Sentient and voluntary nerves are blended with the excitor and motor nerves, but their functions are suspended, when the influence of the centre of this system is cut off. The centre of the excitor and motor nerves being the appropriate portions of the spinal marrow itself, the functions of these nerves remain.

38. Still the two sets of nerves are generally blended anatomically. If they be distinct in any class of animals, it is probably in the *Invertebrata*, (see § 33.) and especially in their lowest forms, in which sensation and volition are nearly extinct, and the animal lives a sort of excito-motory life only.

39. But if the existence of a *distinct* anatomy of the excito-motory

system be doubtful, that of the *blended* anatomy, and that of the distinct physiology, pathology, and therapeutics of this system, are perfectly obvious.

40. Fig. 3, in Plate I., Plan IV., represents the simplest form of the system of excitor and motor nerves. Fig. 2 and 3, Plan IV., represents more distant arrangements of the same kind.

41. I think I may regard the proof as quite complete, that the principle formerly designated the vis nervosa, and that which operates in producing that series of actions, which have been designated instinctive, automatic, sympathetic, &c., but which I propose to designate excito-motory, are one and the same. The incident, retrograde, and reflected courses, and the combined forms, in which it operates, are at variance with the laws of its operation, deduced from the facts formerly known, by Prof. Müller, and afford the *type* of the extensive series of physiological, pathological, and therapeutic phenomena to which I have alluded.

42. The experimental fact noticed, § 20, and represented, Plate I., Plan II., Fig. 4, gives the type of all those physiological phenomena in which the excito-motory property acts, first in an incident, and then in retrograde and reflex directions, and in *combined* modes, as we observe in the excited acts of ingestion and expulsion, and in the action of the orifices and sphincters.

43. The same fact represents the effects of dentition. The experiment detailed, § 17, and represented Plate I., Plan II., Fig. 3, affords us the type of traumatic tetanus.

44. The therapeutics of agents which operate through the excito-motory system are still nearly unknown, and require a careful investigation. Strychnine, besides acting on the general excito-motory system, is apt to affect the larynx [1]; cantharidine, the cervix vesicæ, &c.

[1] See the Lancet for November 8th, 1834.

45. This brief view of the excito-motory system, appears to me to consist in a series of experiments and observations, rather than of deductions. It is, therefore, scarcely liable to error; its originality is obvious; its importance will be made manifest as we proceed.

Sect. II.—*Opinions of former Physiologists.*

46. I now proceed to give a slight sketch of the opinions of physiologists upon the subject of this Memoir.

47. I need scarcely advert to the observations of Haller and of Monro. The former considers the cerebrum as the organ of sympathetic[1] actions. He observes; "Collecta hæc omnia evincunt, graviorem in nervis irritationem *cerebrum* primum in consensum ciere, deinde in universis musculis convulsionem excitare." Monro[2] concludes, "It may be sufficient to know the stimuli which excite the spontaneous motions, the manner in which they are performed, and to be convinced that we cannot account for them by the known texture of the body."

48. But it is to Whytt, of all the authors of a former day, that we are indebted for the most detailed view of this subject. And what are the conclusions of this writer? "If the motions of the muscles in a cock's limbs, after decollation, are, without doubt, owing to its *soul* (!), may we not also ascribe to the *same* principle the *like*, but less remarkable motions, in men and quadrupeds, after their heads are struck off, and, consequently,

[1] Elementa Physiologiæ, tom. iv. p. 337.

[2] On the Nervous System; Edinb. 1783. p. 104.

the tremulous motions and palpitations of their *hearts* (!) too, after death or separation from their bodies[1]?" "Nor is it" (the soul) "influenced by any rational motives, but merely by the stimulating causes affecting the several organs; i. e., it acts as a SENTIENT, and not as a RATIONAL principle[2]" (!). "The various sympathetic motions of animals, produced by irritation, are owing to particular *sensations* excited in certain organs, and thence communicated to the *brain* or spinal marrow[3]."

49. Of all the writers upon this subject, of a period a little remote, Sir Gilbert Blane, Bart.[4] has approached most nearly to the truth, in an isolated paragraph which I shall give entire:—"There are facts which show that instinctive actions, even in animals endowed with brain and nerves, do not depend on sensation. I took a live kitten, a few days old, and divided the spinal marrow, by cutting it across at the neck. The hind paws being then irritated by pricking them, and by touching them with a hot wire, the muscles belonging to the posterior extremities were thrown into contraction, so as to produce the motion of shrinking from the injury. The same effects were observed in another kitten, after the head was entirely separated from the body. In repeating this experiment, I found that when the spinal marrow was cut through, between the *lumbar vertebræ* and *os sacrum*, the *posterior extremities* lost their irritability, but the part below it, *the tail*, retained it. It might, therefore, be said, that the spinal marrow below the division, served as a sensorium; but it may be answered, that when the head is cut off, its irritability remains, as appears by the motion of the ears, when pricked or touched with a hot wire; and as the extremities are also irritable, it will

[1] Whytt's Essay on the Vital Motions; Edinb. 1751. p. 389. [2] Ibid. p. 320.
[3] Whytt's Works; p. 510. [4] Select Dissertations; p. 262.

not be said that consciousness and sensation exist in two separated portions of the same body. Nor can it be admitted that sensibility and consciousness may remain in the head after separation; for, if mere compression of the carotid arteries abolishes sensation and thought, by interrupting the circulation in the brain, how much more must the superior violence of decapitation have this effect? In an acephalous monster, the like *phenomena* were observable. It moved up its knees when the soles of the feet were tickled: it performed the act of suction; passed urine and fæces, and swallowed food. It is on record that the same took place in the case of one, in which the spinal marrow, as well as the brain, was wanting (!). The like takes place with regard to insects; for, after the head of a bee is separated from the body, the hinder part will sting, upon the application of such a *stimulus* as would excite the same action in the animal in a perfect state. These facts show clearly that instinctive, or rather automatic motions, may be exerted, without the intervention of the *sensorium commune*, and, therefore, without sensation or consciousness."

50. There are many interesting experiments in the admirable work of Legallois, which bear upon the subject of this Memoir. But they remain isolated and unapplied, and are referred to sensation. Legallois[1] observes: "La vie du tronc dépend de la moëlle épinière, et celle de chaque partie dépend spécialement de la portion de cette moëlle dont elle reçoit ses nerfs. De plus, il est facile de démontrer que cette prérogative de la moëlle épinière, d'être la source du sentiment et de tous les mouvemens volontaires du tronc, lui appartient exclusivement à tout autre organe."

51. The Reporters of the Institute adopt the erroneous conclusions of

[1] Œuvres de Legallois, Paris, 1824, tome i. p. 251.

Legallois: "M. Legallois," they observe[1], "a démontré que la section de la moëlle épinière sur les premières ou sur les dernières vertèbres cervicales, n'arrête que les mouvemens inspiratoires, et qu'elle laisse subsister dans tout le corps le sentiment et les mouvemens volontaires. Cette distinction est capitale: personne ne l'avait faite avant lui."

52. In Mr. Mayo's recent edition[2] of his useful work on Physiology, I find a notice of my researches on the Nervous System, which requires a short reply. Mr. Mayo observes, p. 534,—"Under the name of reflex function of the spinal cord," Dr. M. Hall has investigated a principle, which was explicitly laid down in my Anatomical Commentaries, published in 1823, (Part II. p. 138,) in the following words:—"An influence may be propagated from the sentient nerves of a part to their correspondent nerves of motion, *through the intervention of that part alone of the nervous centre, to which they are mutually attached.* Thus in vertebral animals, in which alone the fact is questionable, when the spinal cord has been divided in two places, an injury of the skin of either region is followed by a distinct muscular action of that part. Again, if the brain is quickly removed from the head of a pigeon, leaving only the crura cerebri, together with the tubercles, and the second and third nerves, on pinching the second nerve, the iris contracts.

53. "The same view and the same facts, *carefully distinguished from the agency of sensation and volition,* have been put forward in the former editions (as in the present) of my Outlines of Physiology."

54. Mr. Mayo must surely have a treacherous memory. He has not only *not* "*carefully distinguished* this view from the agency of sensation and volition," but he has, in several paragraphs, *explicitly* confounded them together. I shall adduce one. Both in the *third,* (p. 230,) and in the *last,*

[1] Œuvres de Legallois, Paris, 1824, tome i. p. 251.

[2] Ed. 4. 1837. p. 834.

(p. 212,) editions of the Physiology, we find the following passage :—"Each segment of the double cord, from which a pair of nerves arises, has in itself a mechanism of *sensation* and instinctive action, comparable to the parallel parts in articulate animals. The proof of this is contained in the following remarkable experiments made upon the body, a few seconds after it has been deprived of life. If the spinal cord be then divided in the middle of the neck, and again in the middle of the back, upon irritating a *sentient organ* connected with either isolated segment, muscular action is produced: if the sole of the foot is pricked, the foot is suddenly retracted, with the same gesture as it would have been during life; that is to say, a *sentient organ* is excited, and an irritation is propagated through the *sentient nerve*, to the isolated segment of spinal marrow, when it gives rise to some change, which is followed by an impulse along the *voluntary nerves* to the muscles of the part." Mr. Mayo actually speaks of "*sensation*;" and he speaks of a *sentient* organ, a *sentient* nerve, a *voluntary* nerve, phrases which have no meaning, if they do not imply *sensation* and *volition*. Certainly Mr. Mayo's views are NOT "*carefully* distinguished from the agency of sensation and volition."

55. M. Flourens[1] has taken two most important steps in this investigation: he first traces *sensation* to its sole and peculiar organ, the *cerebrum*; and, in the second place, assigns the *spinal marrow*, exclusively of the cerebrum and cerebellum, as the special organ of the *excitabilité*, and of the *sympathies*, and the medulla oblongata as the *combiner* of the acts of respiration. I consider M. Flourens' work as amongst the most splendid in physiology.

56. Dr. Alison has treated the "principle of sympathy" at great length

[1] Du Système Nerveux, pp. 35; 15.

in a very able paper published in 1826 [1]. He concludes [2]: "We have seen evidence sufficient, as I think, to induce us to acquiesce in the proposition, that these (sympathetic) actions most generally depend on the excitation of particular *sensations*. In order that these sensations may be felt (!) the nerves, from the impressions on which they proceed, must be *entire up to the brain* [3]; but when they are strongly felt, their influence extends, or is reflected downwards, often to parts of the nervous system remote from those in which they originated. Each acts as a stimulus, or excites an involuntary instinctive impulse, which acts as a stimulus on particular muscles only; and we cannot tell why. This was the doctrine of Whytt, of Monro, and of Haller. Modern physiologists have rendered it somewhat more precise, only by determining the portions of the encephalo which appear essential to the sensation, and those actions of nerves, in consequence of them, taking place." Dr. Alison adds: "Farther than this, in the explanation of sympathetic actions, I cannot go." This may be perfectly true. But it appears to me that Dr. Alison himself proceeds a step too far, when he concludes: "and I will venture to affirm, that whoever does go further, goes on hypothesis, and will find himself opposed by facts."

57. Since the publication of my former Memoir, I have been greatly gratified to find that Prof. Müller, the justly celebrated physiologist of Berlin, had been led, entirely independently of me, into the same path of investigation,—to nearly similar results,—and even to the adoption of the

[1] Trans. of the Med. Chir. Soc. of Edinb. 1826; vol. ii. p. 165. [2] Ibid. p. 222.

[3] This statement is a little at variance with a more recent statement of the author in question in his Outlines of Physiology, 1833, p. 131; and in a still more recent injurious criticism in a medical journal; see British and Foreign Medical Review, and compare vol. iii. p. 34. 579, and 580 note.

same designation for the special function of the spinal marrow which is the subject of my inquiries.

58. Prof. Müller particularly observes that the first part of his "Handbuch," containing the principles of the reflex function, was published in the spring of 1833, the very year in which my paper was published in the Philosophical Transactions. I had, however, read a short account of the same principle of action in the spinal marrow, to the Zoological Society, the year previously, viz. 1832, which was published in the "Proceedings of the Committee of Science" of that Society; so that the question of priority of publication is indubitably in my favour. Besides, Prof. Müller still refers the phenomena in question to *sensation*, and includes the *brain* amongst the central organs of the reflex function. On these two points, therefore, our opinions differ. At the same time, the almost perfect coincidence in our observations and experiments, and in our conclusions from them, is at once most remarkable and satisfactory. The influence of Prof. Müller will not fail to give importance to the inquiry; and, for my part, I recall to mind, with pleasure, the remark of Sir Humphry Davy, that "we may generally discover how our labours will be appreciated eventually, from the opinion of contemporary foreigners, who being unbiassed by circumstances of personality, will reduce every object to its just proportions and value."

59. I will now briefly advert to the progress of my own investigations. The first fact which I observed, in reference to the excito-motory power of the spinal marrow, was the movement of the separated tail of the salamander, when irritated by a needle; a subsequent observation, was that of the tetanic condition of the same part, when separated from the rest of the animal under the influence of strychnine. It is difficult to imagine the

first, and impossible to imagine the *second* of these phenomena to be dependent on *sensation*; the former, in fact, is one of the excito-motory property in its natural condition; the latter one of the same property in a state of exaltation.

60. I next proceeded to investigate the relation of the excito-motory power to the closure of the eyelids, the occasional actions of the larynx, pharynx, and expulsors, and the constant action of the sphincters; and my attention has, since the publication of my former Memoir, been particularly directed to the acts of respiration, as an important part of the functions of the excito-motory system, hitherto misunderstood [1].

61. I have especially been led to consider the Anatomy, the Physiology, the Pathology, and the Therapeutics, of the excito-motory system, as subjects requiring an extended and almost exclusive investigation.

62. It appears to me that I have taken two important steps:—the first, that of having separated the phenomena of which I am treating from *sensation*; the second, that of having traced them to the *vis nervosa*, or *motoria*, and arranged them in the same class as those observed on irritating the spinal marrow, or a motor nerve. These last movements have been observed to be simple and direct; and it had never been imagined that the same principle of action frequently operates in a retrograde, reflex, and complicated manner. It is obvious, however, from the experiments and facts of this paper, that the medulla oblongata and spinalis is the *centre* and *combiner* of these complicated movements, which are further produced through the medium of incident, and *excitor*, and reflex and *motor*, *nerves*.

[1] See Memoir I., § 9, 49, &c.

Sect. III.—*The Influence of Sensation in inducing Motion.*

63. There is no *immediate* [1] connection between sensation and motion. But there are two modes in which sensation may induce motion: the first is through *volition;* the second through *emotion.*

64. If pleasure or pain be experienced, the sensation is frequently followed by an act of volition issuing in voluntary motion. We close our eyes to avoid a too brilliant light. We withdraw our hand from any cause of pain. But the fact is too familiar to require illustration.

65. The influence of sensation in inducing emotion and consequent motion, is, I think, less understood. The sight of a disagreeable object acts in inducing disgust and sickness. That this event is the effect of emotion is proved, first, by its being observed on the mere *recollection* of the disagreeable object; and, secondly, by the frequent concurrence of another event not of the same kind, viz. syncope.

66. I may now revert to my proposition—that there is no immediate connection between sensation and motion; and I will endeavour to show that all those phenomena which *appear* to denote such a connection, are, in reality, of a totally different nature. I shall commence my observations by the detail of an experiment.

67. *Experiment* 1.—A horse was struck with the poll-axe over the anterior lobes of the brain. It fell instantly, as if struck with a thunderbolt; it was convulsed, and then remained motionless. It shortly began to breathe, and continued to breathe freely by the diaphragm. When lacerated or pricked by a sharp or pointed instrument, as a *pin*, or a *nail*, on any part of the face or surface of the body, it was totally motionless, manifesting no

[1] See Memoir I., § 25—27.

evidence of sensation or volition. When, on the other hand, the *eye-lash* was touched with a *straw*, the eye-lid was forcibly closed by the action of the *orbicularis*. When the cornea was touched, the eye-ball revolved outwards, by the action of the *abducens*. When the verge of the anus was touched, the *sphincter* contracted forcibly, the tail was raised, the vulva was drawn towards the anus. The upper part of the medulla oblongata was now destroyed by an instrument passed through the orifice made by the poll-axe: there were violent convulsions; the respiration ceased, and the eye-lid and eye-ball remained motionless on the application of stimuli.

68. In this experiment, after the blow of the poll-axe, I *first* sought for evidence of sensation, and could discover none. The infliction of a lacerated wound induced no manifestation of pain. I concluded, therefore, that sensibility was annihilated. I *then* touched the eye-lash and the border of the rectum with a straw, and the eye-lid and the sphincter ani immediately contracted. There is something, then, in these phenomena, different from sensation.

69. *Exp.* 2.—I removed the head of a snake. It continued to move about on being excited, as each successive movement brought a fresh part into contact with the table. I was called away. On my return, I found it with one-third of its body suspended over the acute edge of the table. A more painful position cannot be imagined, if we suppose the creature endued with sensation. It is, therefore, certain that sensation was extinct.

70. *Exp.* 3.—I took two eels, and removed the head of each. I placed them upon a table, previously moistened with water; one of them being pierced with many large needles. Both were equally motionless when untouched: both were equally excitable on the application of any cause of irritation. Had the slightest sensibility remained, the eel pierced with needles must have writhed continually.

71. *Exp.* 4.—I removed the head of a frog, and suspended the animal

by means of a ligature tied tightly round the toes. It remained motionless. I then pinched the skin in various parts: there was invariably forcible muscular contraction; and then the elongated form was resumed as before. The effect was precisely similar to that observed in another decapitated frog, on irritating the spinal marrow or a muscular nerve. Had there been sensation, or sensibility, there must have been repeated, or rather continual, and spontaneous movements; whereas there were only *single* movements, or movements repeated *once*, and then only on the application of a stimulus.

72. *Exp.* 5.—I performed the same experiment on a snake, with precisely similar results. On each application of a stimulus, the snake was flexed in a zig-zag or waving form. It then gradually *fell* into a straight line, and ceased to move until a fresh stimulus was applied.

73. We are thus led to conclude, that sensation is extinct in all parts of an animal whose spinal marrow has been divided, situated below the point of division; excito-motory phenomena remaining. But we have still more positive proofs of the same facts in cases of injury of the spinal marrow in the human subject.

74. *Case* 1.—I am indebted to a most intelligent pupil, Mr. W. F. Barlow, of Writtle, Essex, for the following interesting case:—"John Bright, aged 19, climbed up a walnut-tree, on the 1st of October, 1836, for the purpose of picking the fruit; and, when he had attained a very considerable height, slipped, and was precipitated to the ground. He was soon afterwards found in a cold and pulseless condition, with his lower extremities numb and motionless."—"There were obstinate constipation, which was overcome by strong purgatives, and retention of urine, which required the introduction of the catheter."—"The following was the condition of the patient, three months after the accident. The lower half of his body and inferior extremities were entirely devoid of sensation, and they were not in the

slightest degree under the influence of the will. Sometimes the patient had cold shiverings; and whilst the muscles of that part of the body supplied with nervous energy from above the seat of injury were observed to shake, those deriving their nerves from below that spot were perfectly motionless." —"Notwithstanding the anæsthæsia, and the patient's inability to effect a single movement through the medium of volition, when the integuments of the legs were pinched, or more particularly when the sole of the foot was tickled, the extremities were retracted with considerable force. A little cold water dashed upon the surface produced the same effect, though there was no feeling of coldness. One leg was constantly in the flexed position, and if straightened, immediately recovered it again. When the catheter was introduced, the penis was excited into a state of complete erection, an effect consequent upon the gliding of the instrument along the urethra; at the same time the legs were drawn up, and a twitching of their muscles was very obvious." The spinal marrow was found, post mortem, to be nearly severed in the neck.

75. I am indebted to Dr. Budd for a case of paraplegia, in which the most extraordinary and forcible movements of the limbs took place whenever the bowels were relieved. In a case recently detailed by Sir B. C. Brodie, Bart., to the Royal Medical and Chirurgical Society, effects similar to those described by Mr. Barlow, took place on passing the catheter, the patient being totally unconscious of the contact of the instrument, and of its effect. Lastly, M. Brachet details a case in which a person perfectly paraplegic became a father,—the *συνουσια* being "sans sensation," "sans secousse."

76. I may here revert to the well known experiments already noticed; § 11, 12. If a muscular nerve be stimulated either mechanically or by galvanism, the muscle or muscles to which it is distributed are excited into contraction; if the spinal marrow be stimulated in a similar manner, the muscles

of the parts or limbs to which the spinal marrow sends its nerves, are excited into contraction. Has any one imagined sensation to be involved in any of these phenomena? And if not, why should we imagine its existence when we take two steps farther, and produce retrograde and reflex actions by stimulating the spinal marrow, or an incident nerve? Lastly, no one has supposed the pathological conditions of the reflex and excito-motory function of the spinal marrow to depend on sensation. Tetanus, whether traumatic or induced by strychine, has never been referred to *sensation* as its cause. The same remark may be made in reference to all the diseases, centric or eccentric, of the spinal marrow.

Sect. IV.—*Experiments upon the Excito-motory Property.*

77. The preceding experiments and cases appear to me to prove, in the most indubitable manner, that a series of motory phenomena exist, under circumstances in which sensation, volition, emotion, and every function of the brain have ceased. This was the first question to be determined; and I regard it as determined in a manner doubly opposed to the opinions of all former physiologists, inasmuch as it is proved to be, *not sensation, but* the *vis nervosa*. The next question is,—What are the *Laws* according to which this power operates? This question can only be determined by a series of experiments. A part of such a series of experiments, the general results of which have been already given, § 11—28, I proceed to detail.

78. *Exp.* 5.—The first of these was performed on the turtle. The head, the sternum, and the tail, were removed in the ordinary way.

79. 1. The *head* being properly placed upon the table, I first stimulated, successively, by means of the galvanic influence and the forceps, the lowest portion of the medulla, and of the pneumogastric nerve; I then irritated, successively, the nostril, the palatine fringes, and the internal

part of the larynx. In *all* these cases, an act of inspiration—the descent of the sub-maxillary textures—was excited. I then stimulated, in succession, the lower portion of the spinal marrow, the intercostal nerves, and various parts of the general surface of the *trunk*. In *all* these experiments the anterior fins were moved.

80. *All* these phenomena ceased on removing the medulla oblongata and the medulla spinalis.

81. *Exp.* 6.—In another experiment, I first removed the head of a young turtle.

82. 1. On pinching and galvanizing the lower extremity of the medulla oblongata, there was an excited act of inspiration. The same event occurred on stimulating the nostril, the intra-maxillary or palatine fringes, and the internal part of the larynx.

83. 2. I then laid bare the middle portion of the spinal marrow, by removing part of the shell. On pinching or galvanizing this, *both* the *anterior* and the *posterior* fins were moved.

84. 3. Lastly, I removed the sternum and laid bare the intercostal nerves. On stimulating these by the forceps, or galvanism, *both* the *anterior* and the *posterior* fins were moved as before. The same event took place on stimulating any part of the cutaneous surface.

85. 4. If an intercostal nerve be chosen situated near the anterior, or near the posterior fins, these are respectively more moved than those situated more remotely.

86. *Exp.* 7.—I next took a frog, separated the head, and divided the spinal marrow low in the back; I then stimulated the lower end of the upper portion of the spinal marrow with the forceps; the anterior extremities moved in the most remarkable manner:—they were gently raised, without being affected with the *twitchings* seen in the inferior extremities when the upper part of the lower half of the divided spinal marrow was stimulated.

87. *Exp.* 8.—I next performed a nearly similar experiment upon the lobster.

88. I laid bare the nervous columns.

89. 1. I first stimulated one of the inter-ganglionic nerves. The muscles to which it was distributed, and *they alone*, were contracted.

90. 2. I then stimulated a ganglionic nerve. Muscles, both *anterior* and *posterior* to the part stimulated, were excited into combined action.

91. 3. The same event occurred when I stimulated a part of the general or combined nervous column itself.

92. I was next anxious to perform these experiments on an animal of warm blood. I chose, for this purpose, a rabbit of six days' old.

93. *Exp.* 9.—I first removed the head. I then stimulated the lower end of the divided medulla. There was an immediate act of *gasping*. I then divided the spine in the back, and stimulated the lower end of this middle portion of the spinal marrow. The anterior extremities were immediately moved.

94. The next experiment which I shall detail, although deeply interesting, is *not* so satisfactory. It was performed upon a donkey. The head not being removed, sensibility might blend itself with the phenomena of the excito-motory property. See § 98.

95. *Exp.* 10.—Mr. Field laid bare the pneumogastric and sympathetic nerves in the neck of a donkey one year old. The pneumogastric nerve was pinched with the forceps without producing any effect. It was then pinched continuously for a short space of time: there was then an act of inspiration, followed by an act of deglutition, and shortly afterwards by a general struggle. Similar experiments were made upon the sympathetic nerve without producing any effect whatever.

96. It is obvious, from these experiments, that the nervous agency in these phenomena is identically the same as that which acts *directly* in the

experiments of Haller, M. Flourens, &c. It is obvious that this agency, contrary to the views of Haller, Prof. Müller, &c., pursues other directions besides that of the branches, or fibres, of nerves; directions which are incident, retrograde, and reflex in regard to the spinal marrow. It is obvious from this course of the nervous agency, or vis nervosa, that there exists certain nerves which, like it, are incident and reflex.

97. How important is it, that the anatomy and physiology, the pathology and therapeutics of this nervous power should be pursued!

98. Before I conclude this Section, I must make a few remarks upon some interesting experiments of Prof. Müller. They are published in the "Annales des Sciences Naturelles" for 1831, Vol. XXI., and in the "Handbuch der Physiologie," p. 625. The first of these experiments is that in which the stimulus is applied to the posterior roots of the spinal nerves, in the frog. No movements were observed in the anterior parts of the animal, as the head. This result is opposed to that which I have uniformly observed in the turtle. The second is that in which the lower part of the spinal marrow is laid bare and irritated: movements *were* then observed in the anterior parts, as the *head*[1]. The circumstance of the head being present, prevents us, however, from distinguishing these movements from those induced by sensation. See § 94.

99. Prof. Müller concludes that there is something more in the spinal marrow than a nerve or chord of nerves. And this is, I believe, true, although not the legitimate conclusion from Prof. Müller's experiment, as I have stated. Prof. Müller considers, on the other hand, that there is some difference between the *nerves* and the spinal marrow, as the posterior roots were not, in his experiments, excito-motory. This conclusion must not be generalized, since the posterior roots of the turtle *are*, as well as the spinal marrow, possessed of the excito-motory power.

[1] See Annales, &c. p. 106, l. 22—24. Handbuch, 632.

Sect. V.—*Distribution of the Nervous System.*

100. The entire nervous system has usually been divided into the cerebro-spinal and the ganglionic. This view of the subject confounds two distinct parts of the system, which it is my express object to distinguish. The *cerebro-spinal* system consists obviously, indeed, of the *cerebral*, which comprises the sentient nerves, the cerebrum, and the nerves of volition: and the *true spinal*, which, as I shall proceed to state, immediately, consists of a series of excitor nerves, of the true spinal marrow, and a series of motor nerves.

101. The whole nervous system may, therefore, be divided into

I. *The Cerebral, or the Sentient and Voluntary;*

II. *The True Spinal, or the Excitor and Motor; and*

III. *The Ganglionic, or the Nutrient, the Secretory, &c.*

102. The cerebral system is sketched Plate III., Fig. 1. I have represented the *sentient* and *voluntary* nerves as proceeding *to* and *from* their central point, or union, the *cerebrum*.

103. The true spinal system is represented Plate III., Fig. 2. In this system the excitor and motor nerves are pourtrayed as proceeding variously *to* and *from* the *spinal marrow*, in its different portions, whether viewed as *segments*, or as disposed *longitudinally*.

104. The difference between these two systems is most obvious and remarkable. From their relative distribution and connexion, it is easy to foretel the effects of disease or of injury. If we sever the cerebrum from the true spinal marrow, sensation and volition, with all spontaneous movements, must cease; the excito-motory phenomena alone remain. Disease of the cerebrum, by severing the cerebral origin of the trifacial

nerve, whilst its spinal origin remains (see § 131), may produce paralysis of sensation and voluntary motion, in the face for instance, whilst the eyelids and the nostrils are as excitable as ever. But if we destroy the trifacial nerve, which involves in its neurilemma not only the sentient, but the excitor nerve, *both* sensation and excitability are extinct.

105. The functions of the cerebral system are,—sensation, perception, judgment, volition, voluntary motion. The sensations are conveyed to the cerebrum by the sentient nerves,—the olfactory, the optic, the acoustic, the glosso-pharyngeal (?), and the trifacial and posterior spinal; the cerebrum itself may be viewed as the organ of mind,—that organ on which the ψυχη sits, as it were, enthroned; the voluntary nerves convey the mandates of the volition to the muscles which are to be called into action. All these functions are strictly *psychical*. They imply consciousness. Sensation without consciousness appears to me to be a contradiction in terms; the idea and the phraseology should be banished from physiology.

106. The cerebral system *sleeps:* sensation is dull, volition quiescent. Dreams, &c. are the delirium of sleep.

107. How different from those which I have thus enumerated, are the functions which belong to the true spinal marrow! In these there is no sensation, no volition, no consciousness, nothing psychical. An impression is made upon the extremity of a nerve; this impression is conveyed, not to the cerebrum, but to some part of the medulla oblongata or medulla spinalis; whence it is reflected upon certain muscles destined to be excited into consentaneous action.

108. The true spinal system is independent of the cerebrum, and subsists when the cerebral lobes are removed. It guards, as it were, the orifices and exits of the body, regulating the ingesta and the egesta.

109. The cerebral system is the seat of the intellect; the true

spinal marrow is, in an especial manner, the organ of the emotions and passions. It is on this part of the nervous system that the preservation of the individual and the continuation of the species depend.

110. The cerebral system connects us with the external world in everything that relates to sensation and volition, or mind; the true spinal system, in everything that relates to the appropriation of its materials, or their expulsion,—in everything that, in those respects, relates to nutrition and reproduction.

111. The assimilation of the ingesta, and the preparation of the egesta, are subjected to the control of the *third* subdivision of the nervous system, or the *ganglionic;* in which, I think, there is good reason to include, with that usually denominated the grand ganglionic or sympathetic nerve, the ganglionic of the face, or trifacial, the pneumogastric, and the posterior spinal nerves.

112. The argument for such an opinion is this: there is an internal nerve destined for formation, nutrition, secretion of the internal organs; this nerve is ganglionic: there are external organs and structures, the superior and inferior extremities, for example, requiring nutrition; there are external ganglionic nerves. The conclusion seems to be inevitable, that these constitute the external nutrient or ganglionic system. They are *plexic* as well as ganglionic, because they are compound, and involve sentient and excitor nerves with the ganglionic. The internal ganglionic system is simple, and *purely ganglionic* in form, having no such addition.

113. Each part of the nervous system is the special seat of a particular class of diseases; augmented sensation and volition, and paralysis of sensation and volition are pathological states of the cerebral system: *all spasmodic* diseases are attached to the excito-motory system, or the true spinal marrow; certain affections of nutrition and of the secretions belong to the ganglionic system.

Sect. VI.—*The Cerebral, or Sentient and Voluntary, System.*

114. It is not my present intention to pursue the subject of the cerebral system. I shall merely present my reader with the following arrangement of this system, observing that every compound sentient and excitor, or voluntary and motor, nerve, must be presumed to have *two* origins, *one cerebral, the other spinal.*

Table of the Cerebral, or Sentient and Voluntary System [1].

I. *The Sentient Nerves.*
1. *The Olfactory.*
2. *The Optic.*
3. *The Trifacial.*
4. *The Acoustic.*
5. *The Glosso-pharyngeal.*
6. *The Posterior Spinal.*

II. *The Cerebrum and Cerebellum, the Centre of the System.*

III. *The Voluntary Nerves.*
1. *The Oculo-Motory.*
2. *The minor portion of the Trifacial, or Masticatory.*
3. *A part of the Facial.*
4. *The Myo-Glossal.*
5. *The Anterior Spinal.*

1. In their course *within* the *Cranium.*
2. In their course *without* the *Cranium.*
3. In their course *within* the *Spine*, generally viewed as the *Spinal Marrow.*
4. In their course *without* the *Spine.*

[1] See Plate III. Fig. 1.

Sect. VII.—*The True Spinal, or Excito-Motory System.*

115. The true spinal *marrow*, as distinguished from the *chord* of cerebral, sentient, and voluntary *nerves*, with which it is inseparably blended in structure, is the centre or axis of a distinct system of excitor and motor nerves, hitherto unknown to physiologists.

116. This excito-motory system of nerves presides over ingestion and exclusion,—over retention and egestion, and over the orifices and sphincters of the animal frame. It is, therefore, the nervous system of respiration and deglutition, and of the retention and expulsion of the fæces and urine, and of the semen.

117. By means of this system, that "tourbillon" of the ingesta and egesta, so beautifully and eloquently described by Cuvier, is effected. By means of this system, the animal frame is constituted a casket, guarded at the upper part, and securely closed at the lower.

118. The excito-motory, or true spinal system, is the nervous agent in all those *motions* hitherto confessedly not understood, by the fact of their being designated by the unmeaning term *sympathetic*, &c.

119. This system is also the source of *tone* in the whole muscular system.

120. The true spinal system is, in a peculiar sense, the seat or nervous agent of the appetites and passions. Through it the emotions affect, not the expression and the respiration alone, but the pharynx, the larynx, the sphincters, the expulsors, and indeed the whole muscular system of the animal frame.

121. The true spinal system is susceptible of *modification* by volition, and, on this account, some of its functions have been denominated *mixed*. It is also constantly under a certain influence of the volition, as is manifest

in the difference in the respiration, &c., during intense mental attention, sleep, and coma, and in ordinary circumstances.

122. The true spinal system *never sleeps;* respiration and deglutition, the action of the orifices and sphincters, are continued.

123. That a principle so extensive and important in the animal economy should not have been detected and known before, must appear extraordinary. And that such is the fact, may be demonstrated by considering the most simple and familiar examples of the functions over which this principle presides. Has it been stated in any work, ancient or modern, that the deglutition of water by the pharynx, the exclusion of carbonic acid by the larynx, the retention of the urine and fæces by the sphincters, are exclusively functions of the *spinal marrow, and* of a peculiar *System* of *excitor* and *motor* nerves, of which it is the centre or axis? I have looked, in vain, over the works of Dr. Bostock, Dr. Alison, and of Mr. Mayo; of M. Adelon, and M. Magendie; and of Rudolphi and Prof. Müller, for an account, or even a hint, of such a principle, as involved in these familiar acts.

124. Nay, the idea of a system of *excitor* nerves, constantly operating in the animal economy, preserving its orifices open, its sphincters closed, and constituting the *primum mobile* of the important function of respiration, I believe to be new. The acts are so familiar to us, that we have thought them understood, when the nervous agents through which they have been *excited* have not even been detected. Yet, that this view is the true one, is proved by the most decisive experiments.

125. The nearest approximation to the detection of this system, is to be found in relation to the closure of the eye-lid on touching its borders. M. Magendie observes[1], "Le mouvement, nommé *clignement*, dépend en

[1] Précis de Physiologie; Paris, 1833, t. i. p. 51.

partie du nerf facial, et en partie du nerf de la cinquième paire. Il cesse quand le nerf facial est coupé ; il cesse ou ne se montre que très-rarement, et seulement par l'effet d'un rayon directe de lumière solaire, quand le nerf de la cinquième paire est divisé. La perte du mouvement des paupières par la section, ou la paralysie du nerf facial, s'entend facilement, puisque ce nerf envoie des filets au muscle orbiculaire. Il est beaucoup plus difficile de comprendre comment la section de la cinquième paire arrête le clignement, car ce nerf, presque entièrement destiné à la sensibilité, n'envoie aucune branche aux muscles qui font mouvoir les paupières." Mr. Mayo observes [1], "The muscle which closes the eye-lids is called the orbicularis palpebrarum; it is disposed for some breadth beneath the skin of the eye-lids in concentric fasciculi. This muscle is supplied by the fifth nerve, and by the portio dura of the seventh, and is paralyzed by the division of the latter. The fifth nerve and the seventh rise together; the fifth imparts sensibility to the eye, to the eye-lids, and eye-lashes; and the least irritation of these parts calls into action the orbicularis palpebrarum, which receives its stimulus through the portio dura of the seventh."—"The *consent* between the fifth and the seventh nerve," &c.[2] These two eminent physiologists are at variance in their anatomy, but obviously attach importance to the question of the distribution of the fifth to the orbicularis itself—so, excluding the very idea of a *reflex* action: the former confesses the difficulty of explanation of the phenomenon; the latter attaches importance to the identity of *origin*, referring the phenomenon to some "consent" between the two nerves,—an opinion controverted with perfect success by Dr. Alison [3] and Prof. Müller [4]. Neither Mr. Mayo nor M. Magendie ap-

[1] Outlines of Physiology, 3rd Ed. p. 307. [2] Opus cit. p. 308.

[3] Trans. of the Med.-Chir. Soc. of Edinb. Vol. II. p. 165. and Outlines of Physiology, 1833, p. 269. [4] Handbuch der Physiologie, 689.

pears to see that the act involves a reflex, excito-motory agency, carried on through the medium of the true medulla,—a fact which is proved by experiments in which the fifth pair of nerves, the medulla, and the seventh pair of nerves, are respectively divided. The central and connecting link between the two nerves, as between the excitor and motor nerves of the true spinal system generally, and in the acts of ingestion and egestion, of the orifices and sphincters, is overlooked.

126. Before I proceed to the details of this paper, I must particularly advert to one function of the true spinal marrow,—the acts of *Inspiration*. As the connecting link between the excitor and motor nerves, in other cases, has been neglected, so the first link, or the excitor nerve itself, has been overlooked in reference to respiration. Legallois [1], Sir Charles Bell [2], M. Flourens [3], Prof. Müller himself [4], all agree in considering the medulla oblongata the *primum mobile* of respiration. I had myself adopted this view of the subject, up to the period of writing my former Memoir [5]. I have since ascertained that, not the medulla oblongata, but the pneumogastric nerve, is that primum mobile, as its excitor, in ordinary respiration, and the fifth and spinal nerves as its excitors in certain extraordinary circumstances. Sir Charles Bell views the pneumogastric nerve as that which *combines* the movements of respiration [6]; whereas, it is really the medulla oblongata which performs that office; so that, in the views of that eminent physiologist, the offices of the medulla oblongata, and of the pneumogastric nerve, have been inverted. In reference to the respiratory system itself, of Sir Charles Bell, whilst I bear my willing

[1] Œuvres; t. i. pp. 64. 237.
[2] The Nervous System, p. 149.
[3] Du Système Nerveux, pp. 180. 184.
[4] Handbuch der Physiologie, 331—.
[5] See § 9, &c.
[6] Nervous System, 1830, p. 46. and Mr. Shaw's Manual of Anatomy, 2nd Ed. 1822, p. 305, note.

testimony to the genius of its author, I must observe, that it is doubly defective: it is, in the first place, only a part—the motor part—of the entire respiratory system; whilst, in the second place, the entire respiratory system is only a part of a more general system—the true spinal, or excito-motory—the agent in all the acts both of ingestion and egestion, respiration itself included.

127. I may conclude this preliminary notice of the subject by the following brief table of the *respiratory nerves*. It consists of the *excitors* of respiration, in addition to the respiratory system of Sir Charles Bell.

System of Respiratory Nerves [1].

I. *The Excitors.*	II. *The Medulla Oblongata.*	III. *The Motors.*
1. *The Trifacial* (1).		1. *The Intercostal* (1).
2. *The Pneumogastric* (2).		2. *The Diaphragmatic* (2).
3. *The Spinal* (3).		3. *The Lower Spinal* (3); *&c.*

128. I will here merely add that the important fact relative to the sentient and voluntary system is, that its centre is the *cerebrum*. This is the opinion of M. Flourens [2], Sir Charles Bell [3]; this *was* the opinion of Dr. Alison [4]. That sensation and volition, and all spontaneous motion cease when the cerebrum is removed, is the uniform result of all my own experiments.

[1] See Plate III. Fig. 2. 4.

[2] Du Système Nerveux. [3] See his last paper in the Phil. Trans. for 1834.

[4] See § 56, and note.

129. In pourtraying this system I have, therefore, Plate III., Fig. 1, represented double lines,—of sensation and volition,—proceeding from the lower and upper extremity, and terminating, or originating, in the cerebrum.

130. Let this sketch be compared with Fig. 2, which represents the incident, downward, upward, and reflex course of the excito-motory power in the medulla oblongata and spinalis, and the broad distinction between the two becomes at once apparent.

131. It becomes obvious that, if a nerve be compounded of sentient and excitor filaments, it has, probably, two origins, one in the cerebrum, the other in the medulla. The same remark is true of the nerves compounded of voluntary and motor fibres (see § 114). Is it possible to trace this structure in any part of the zoological series? What an interesting subject for the scalpel and for experiment!

132. But I must now enter upon the discussion of the anatomy, physiology, pathology, and therapeutics, of the excito-motory system more particularly.

I.—*The Anatomy of the Excito-Motory System* [1].

133. In the *Anatomy* of the excito-motory system there is a rich mine to be explored! In the investigation two modes may be pursued—dissection and experiment. Sir Charles Bell [2] applauds the former, M. Flourens [3] the latter; but all must be agreed that these two methods should be regarded, "not as rivals, but as allies [4]."

134. It may be received as a principle, that every part of the nervous

[1] See Memoir I. § 8.

[2] The Nervous System, p. 217.

[3] Du Système Nerveux, p. xxi.

[4] See Memoir I. § 64, note.

system, which is endowed with the excito-motory power, belongs to this system, whether this power be exerted in the direction of the nerves *from* or *towards* the nervous centres. We have in a simple experiment, therefore, an easy mode of ascertaining what part of the general nervous system belongs to that subdivision of which I am treating. It would be interesting to determine this question in reference to each part of the nervous system of the various Classes of animals.

135. The next enquiry would be, What are the special motions produced by stimulating given incident nerves? The most usual effect produced, is a motion of the limbs. But in other instances we have acts of inspiration, of deglutition, of expulsion,—of closure in the eye-lids, larynx, pharynx, and the sphincters:—interesting facts, which speak a physiological language, and assign distinct and special offices to certain excitor nerves.

136. These excitor nerves may be viewed as *guards* of the orifices and exits of the animal frame. Thus—

I. *The Trifacial guards—*
   1. *The Eye.*
   2. *The Nostril, the Ear,—in the Cetacea.*
   3. *The Fauces.*

II. *The Pneumogastric—*
   1. *The Larynx, the Bronchia.*
   2. *The Pharynx, the Cardia.*
   3. *The Ureter, the Gall-duct.*

III. *The Spinal Nerves—*
   1. *The Rectum.*
   2. *The Bladder.*
   3. *The Vesiculæ Seminales.*
   4. *The Uterus.*

To each part of this series of excitor nerves there is a corresponding set of motor nerves.

137. The whole view of this subject is given in the subjoined *Table*,

and in the accompanying *Plate*; Plate II. It is impossible to view the subject, free from bias and prejudice, without acknowledging that it is one of intense interest.

Table of the True Spinal, or Excito-Motory System.

I. *The Incident, Excitor Branches.*

1. *The Trifacial, arising from—*
   1. *The Eye-lashes.*
   2. *The Alæ Nasi.*
   3. *The Nostril.*
   4. *The Fauces.*
   5. *The Face.*
2. *The Pneumogastric, from—*
   1. *The Pharynx.*
   2. *The Larynx.*
   3. *The Bronchia.*
   4. *The Cardia,—Kidney, and Liver.*
3. *The Posterior Spinal, arising from—*
   1. *The General Surface.*
   2. *The Glans Penis vel Clitoridis.*
   3. *The Anus.*
   4. *The Cervix Vesicæ.*
   5. *The Cervix Uteri.*

II. *The True Medulla Oblongata and Medulla Spinalis, the Centre of the System.*

III. *The Reflex, Motor Branches.*

1. *The Trochlearis* } *Oculi.*
2. *The Abducens* }
3. *The Minor portion of the Fifth.*
4. *The Facial distributed to*
   1. *The Orbicularis.*
   2. *The Levator Alæ Nasi.*
5. *The Pneumogastric or its Accessory.*
   1. *The Pharyngeal.*
   2. *The Laryngeals.*
   3. *The Bronchial, &c.*
6. *The Myo-glossal.*
7. *The Spinal, distributed to the*
   1. *Diaphragm, and to*
   2. *The Intercostal and* } *Muscles.*
   3. *The Abdominal* }
8. *The Sacral, distributed to*
   1. *The Sphincters.*
   2. *The Expulsors, Ejaculators, the Fallopian Tubes, the Uterus, &c.*

[1] See Plate II. and III. Fig. 2.

138. In the sketch of the true spinal or excito-motory system given in Plate II., as in the Table just given, the excitor nerves are arranged on the left hand, and the motors on the right, the spinal marrow intermediately. The pneumogastric nerve is the only exception to this rule; *it* is almost throughout both excitor and motor, and is placed on the left.

139. I believe an objection has been raised against designating a nerve, known to be a sentient nerve, an excitor nerve: but the question is one not of words, but of facts. Is the trifacial a sentient nerve? If so, let it be so designated. Is it also an excitor nerve? If so, there is the same reason for designating it by this epithet. In short, it is not only sentient *and* excitor, but it is, probably, nutrient too. And any view of the subject short of this, is distant from the truth. In the same manner, the pneumogastric must be viewed, not as a mere sentient or secretory nerve, but as emphatically *the Internal Excito-motory Nerve.*

II. *The Physiology of the Excito-motory System.*

140. I have already, § 115—132, given a summary of the physiology of the excito-motory system. I now proceed to enter a little into its details.

1. *Closure of the Eye-lids.*

141. I have alluded, § 20, to the phenomenon of the closure of the eye-lid on touching the eye-lash; and I have shown (§ 125,) that M. Magendie and Mr. Mayo fail to explain it, although both distinctly mention the influence of the fifth and seventh pairs of nerves. A series of interesting experiments demonstrate that the agencies of these two nerves, like those of all the excitors and motors in the reflex function, are combined by the medulla oblongata.

142. I may refer to the experiment on the horse, detailed in a former page, § 67, in which, when sensibility was destroyed, the light touch of a

straw upon the eye-lash, induced a forcible closure of the eye-lid; and to two experiments, detailed in my former Memoir, § 36, 42, in which the touch of the border of one eye-lid induced the firm and simultaneous closure of both.

143. But the most remarkable circumstance connected with the closure of the eyelid, is its relation to the state of *sleep*. I have already stated, § 106, 122, that the cerebral system alone undergoes this remarkable modification; that the true spinal system does not sleep. There must be some remarkable reciprocity between the levator palpebræ and the orbicularis in reference to this phenomenon. When awake, the levator palpebræ is more powerful than the orbicularis; in sleep, the action of the orbicularis prevails. I believe the levator palpebræ, and perhaps the four *recti* of the eye, to be, of all the muscles of the animal frame, purely *cerebral*, or *voluntary*, and unendowed with fibres from the excito-motory system. When awake, volition raises the eye-lid. During sleep, the excito-motory property induces constant contraction of the orbicularis, as it does of the other sphincters. The eye is thus preserved from exposure during the night,—preserved from the state of inflammation with which it is attacked, when, from injury of the facial nerve, or failure of the excito-motory power, the tonic influence of the medulla is cut off, or diminished, and the action of the orbicularis is defective. See § 36. Similar observations apply to the action of the recti, compared with the trochlearis and abducens.

2. *Deglutition.*

144. The next part of the physiology of the true spinal marrow, and of the excito-motory system of nerves, relates to the act of deglutition. In treating of this subject, I must speak principally of the action of the pharynx, but also of that of the cardia.

145. 1. *Action of the Pharynx.*—If we press down the tongue with the handle of a spoon, and convey the instrument towards the root of the tongue and tonsils, an action of deglutition ensues[1]. If in a living animal an incision be made in the side of the neck, and the finger be passed into the pharynx, it is immediately grasped forcibly[2]. The same event occurs even after decapitation in a young animal[3]. In this last case, the action ceases either on dividing the nerves which intervene between the pharynx and the medulla, or by removing the medulla itself.

146. I have looked over the popular works of Dr. Bostock, M. Magendie, and Mr. Mayo, for any intimation of the real nature of the action of deglutition, and of its dependence on the medulla spinalis, in vain. The first of these authors is entirely silent on the subject. The second observes, "Ainsi s'accomplit le deuxième temps de la déglutition, par l'effet duquel le bol alimentaire parcourt le pharynx et s'engage dans la partie supérieure de l'œsophage. Tous les phénomènes qui y co-opérent se passent simultanément et avec une grande promptitude: ils ne sont pas soumis à la volonté; ils diffèrent donc, sous plusieurs rapports, des phénomènes qui appartiennent au premier temps[4]." Mr. Mayo speaks of "the peculiar sensibility of the back part of the fauces" as being "excited," and of the act itself as being "instinctive and irresistible[5]." Mr. Mayo adds[6], "If the action of deglutition be voluntarily performed several times in succession, and nothing but saliva swallowed, the parts become *fatigued*, and the operation cannot be immediately repeated." The real explanation of this last singular and interesting fact is this: an excited act requires a stimulus or excitor; the saliva is that stimulus in the first and second acts of deglutition; but in a third, attempted promptly after the second, this stimulus is

[1] Mayo, Op. cit. p. 112.
[2] Magendie, de l'Usage de l'Epiglotte dans la Déglutition, p. 3.
[3] Müller, Op. cit. p. 696.
[4] Op. cit. II. 68.
[5] Op. cit. 113.
[6] Ibid. p. 114.

wanting; the act consequently fails for want of its excitor. The idea of "fatigue" is obviously fallacious [1].

147. In none of these authors is there the slightest allusion to the important and essential influence of the medulla oblongata in the act of deglutition.

148. 2. *Action of the Cardia.* The cardia opens to receive the food from the œsophagus, and closes to retain it in the stomach. It is paralyzed on dividing the pneumogastric nerves. In a rabbit in which this experiment is performed, the œsophagus is found replete with food, although it may not have eaten after the operation. This fact was first ascertained, I believe, by MM. Leuret and Lassaigne. The pneumogastric is pre-eminently the internal excito-motory nerve.

3. *Closure of the Larynx.*

149. The larynx closes accurately in every act of deglutition, on attempting to inspire carbonic acid [2], on the contact of a drop of water or a crumb of bread, in the act of vomiting, &c. What is the nature of this phenomenon?

150. If, in a living animal, or in an animal deprived of the cerebral lobes, the rima glottidis be touched with a feather or probe, the glottis immediately closes firmly. This phenomenon ceases instantly, in the latter case, on separating the larynx from its connections with the medulla oblongata, by a sharp instrument, within or without the spinal canal, or on destroying the medulla itself. It is, therefore, plainly dependent upon the medulla, and upon excitor nerves which proceed to, and motor nerves which proceed from, this part of the nervous system. It is a reflex, excito-motory act of the superior laryngeals and the medulla oblongata.

[1] See Memoir I. § 14, note 5; § 111.

[2] Pilâtre de Rosier, in the Journal de Physique, xxviii. p. 422. Sir Humphry Davy, in his Researches, p. 472.

151. M. Magendie has written expressly upon the actions of the larynx; and though he concludes from experiment and dissection, that the closure of the larynx depends upon the superior, and its opening upon the inferior laryngeals[1]; and that it is essential that *all* be divided, in order that the larynx may remain open and immoveable,—yet he is perfectly silent upon the essential agency of the medulla oblongata in all excited actions of the larynx. Mr. Mayo ascribes the closure of the larynx from the contact of carbonic acid, water, or mercury, to "the close consent between the sentient mucous surface of the larynx and its muscles[2]."

152. I have thus demonstrated the essential connection of the eyelid, the pharynx, and the larynx, in their acts of closure, with nerves going to and from the medulla oblongata, and with the medulla oblongata itself. I must next proceed to treat of another act, of the same system, the most immediately essential to life of all, viz.:—

4. *The Respiration.*

153. That the respiration is a mixed function, and partly dependent on cerebral agency or volition, is shown by the effect of profound attention, sleep, stupor, the sinking state, &c. During attention or sleep, the respiration becomes irregular and audible; in stupor it is noisy and stertorous; in the dying state it is impaired and catching. In *all* these cases the respiratory movements are instantly improved by rousing the person to sensibility and acts of volition. The partial dependence of respiration on the excito-motory power is made manifest by the division of the pneumogastric nerves: the acts of respiration immediately become much more frequent, and, as M. Magendie expresses it,—"L'animal parait y donner une attention particulière[3]."

[1] De l'Epiglotte; Op. cit. p. 9, &c.

[2] Op. cit. p. 361.

[3] Précis de Physiologie, tome ii. p. 355.

154. From the multitude of opinions respecting the acts of inspiration, it will be sufficient to select three, to be noticed in this place.

155. First, Dr. Wilson Philip [1] and Mr. Mayo [2] consider the acts of inspiration as acts of volition, or of conscious effort.

156. Secondly, Dr. Bostock [3], Dr. W. Philip [4], and M. Brachet [5], consider the acts of inspiration as dependent upon the pneumogastric nerves as nerves of sensation.

157. Thirdly, Legallois, Sir Charles Bell, M. Flourens, Prof. Müller, &c., regard the acts of inspiration as dependent upon the medulla oblongata as their *primum mobile*. See § 126.

158. It appears to me to be a sufficient reply to the opinion that respiration is an act of the will or of conscious effort, that it is repeated when the cerebral lobes, the seat of volition and consciousness, are removed, and when all indubitably spontaneous acts have ceased.

159. And it appears to be a sufficient reply to the idea that inspiration depends upon an uneasy sensation conveyed to the sensorium by the pneumogastric nerves, that it is repeated when these nerves are divided. Dr. Bostock [6] and Mr Mayo [7] speak of this act, and of the agency of the pneumogastric nerves, as imperfectly understood. M. Brachet, speaking of the experiment in which the pneumogastric is divided, observes: "dans ce cas, il ne faut point attribuer la continuation de la respiration au besoin senti de respirer, mais à *l'habitude* que le système nerveux cerebro-spinal a contractée de faire mouvoir les muscles respirateurs [8]!" It is quite unnecessary to make any remark upon this opinion [9].

[1] On the Vital Functions, p. 190, &c. [2] Op. cit. p. 83.
[3] Op. cit. II. p. 46. [4] Op. cit. p. 268. [5] Op. cit. p. 132.
[6] Op. cit. II. p. 46. [7] Op. cit. p. 83. [8] Op. cit. p. 132.
[9] Compare my "Lectures on the Nervous System and its Diseases," p. 24, note 3.

160. I must now make some equally brief observations upon the opinion that the medulla oblongata is the primum mobile of respiration. It is founded upon the facts that the cerebrum may be removed from above downwards, and the spinal marrow from below upwards, without suspending the acts of inspiration, if the medulla oblongata at the point of origin of the pneumogastric be preserved entire. Yet, as M. Flourens observes [1], "La preuve évidente que ce n'est ni uniquement ni même précisément parcequ'elle est l'origine de la huitième paire, que la moelle allongée est le premier mobile de la respiration, c'est que les deux nerfs de la huitième paire peuvent être coupés, et la respiration (quoique dès lors gênée et laborieuse) n'en subsistera pas moins fort long-temps encore." From these several experiments, we should be apt to conclude, that neither the cerebrum, nor the pneumogastric nerves are necessary for the acts of inspiration, since these acts are renewed when either is removed. The truth, however, is, that although the acts of inspiration continue without *either*, they will not continue without *both*. *Each* may be removed *singly;* but *if both* be removed, the inspirations cease, as in the experiment of dividing the medulla oblongata at the origin of the pneumogastric nerves, an experiment hitherto unexplained. In fact, inspiration may be a voluntary act, induced by the agency of the cerebrum, the pneumogastric nerves being divided; or it may be an excited act, excited through the agency of the pneumogastric nerves, the cerebrum being removed. If, in this latter circumstance, the pneumogastric nerves be divided, the acts of inspiration cease! In this last fact we have, then, the proof that the medulla oblongata is not the primum mobile of respiration; but that the pneumogastric nerve is that primum mobile as an excitor of respiration, essential and necessary

[1] Op. cit. p. 181, note.

when the agency of volition, with its organ, is removed,—an important conclusion, by which many difficulties, and an interesting question, are, at once, solved.

161. The acts of inspiration, then, are acts of the excito-motory, or true spinal, system. Ordinary inspiration is excited through the medium of the pneumogastric nerve, but regulated and controlled by the volition. During sleep, and in coma, the influence of volition is diminished or annihilated, and the respiration becomes audible or even stertorous. Respiration is, therefore, as stated of old, a *mixed* function, as indeed are many of the acts of the excito-motory system, excited through particular nerves, but regulated or modified by volition.

162. This remark leads me to observe that the pneumogastric is not the only excitor of inspiration. Inspiration is equally excited through the fifth and spinal nerves; a fact proved by the familiar phenomena induced by dashing cold water upon the extremities of the former in the face, and by impressing the latter by a similar influence on descending into the cold bath. The first act of inspiration in the newly-born infant is probably excited through the medium of the fifth and spinal nerves conjointly, by the contact of the atmosphere, as the first acts of the expulsion of the fæces and urine are excited during the similar contact of the atmosphere with the extremities of the spinal nerves.

163. My friend, Dr. Heming, witnessed an interesting fact in proof of this opinion. The infant just born, and covered by the bed-clothes, did not breathe. Dr. Heming, after waiting a few seconds, proposed to himself to adopt some measure for this asphyxia, and lifted up the bed-clothes. The contact of the cool atmosphere instantly *excited* an act of inspiration! This view of the subject is confirmed by some facts in pathology, to be detailed shortly, and by some experiments.

164. In the first place, if the pneumogastric nerve be laid bare in the

neck of a donkey, and irritated by the forceps, an act of inspiration, followed by an act of deglutition, is actually and instantly excited.

165. In the second place, we have to consider what is the stimulus or exciting cause of inspiration. I must adduce in this place the celebrated experiment of Hook, given in a very early volume [1] of the Transactions of this Society, in which a stream of atmospheric air was driven through the trachea, the lungs, and incisions made through the pleura, in a living dog: the animal made no effort to inspire whilst this stream was continuous; but when it was interrupted, the efforts of inspiration were violent and convulsive. In other words, when the air respired was unmingled with the carbonic acid exhaled by the lungs, no act of inspiration was excited; but when it became charged with that gas, efforts at inspiration were immediately made. Is carbonic acid, then, in the air-cells of the lungs, and in contact with the fibrillæ of the pneumogastric nerves, the exciting cause of inspiration?

166. Other facts confirm this idea. Dr. Faraday particularly mentions the fact, that the respiration can be suspended longer after repeated deep inspirations, by which the air of the lungs is completely renewed, than in ordinary circumstances [2]. Divers breathe less frequently in proportion as they breathe an atmosphere under augmented pressure, and consequently condensed,—the *proportion* or bulk of carbonic acid evolved being less speedily completed. Lastly, the number of respirations is gradually augmented, with gasping, as the proportion of carbonic acid in a given quantity of gas, in which an animal is confined, becomes augmented. It would be interesting to repeat this experiment, taking the precaution of keeping the proportion of the oxygen gas the same. In a word, what pure carbonic acid is in contact with the rima glottidis,

[1] Phil. Trans. for 1667, p. 539.

[2] The London and Edinb. Phil. Mag. vol. iii. 1833.

diluted carbonic acid is in the lungs;—an exciting cause acting through the medium of the excito-motory, or true spinal, system.

167. This principle is corroborated by a circumstance, of which it alone affords an explanation. It has been observed that there is always a certain proportion maintained between the number of pulsations of the heart, and of respirations. This proportion obtains from the highest degree of activity in an animal, even to the most complete quiescence in hybernation. The evolution of carbonic acid is greater in proportion to the rapidity of the circulation; this carbonic acid is itself the exciting cause of inspiration; this act will, therefore, be repeated more or less frequently as the circulation, and with it the evolution of carbonic acid, is more or less rapid. I believe this law of the proportion between the circulation and the respiration has not been explained before.

168. But the experimentum crucis consists in first carefully removing the cerebral lobes with the cerebellum, and then dividing the pneumogastric nerves within the cranium or spinal canal, or in the course of the neck. Respiration subsists as a purely excito-motory act, performed through the agency of the pneumogastric nerves, when the cerebrum is removed; and it ceases immediately when these nerves are then divided.

169. It appears from these various facts, that the acts of inspiration are excited acts, and excited through the medium of several excitor nerves. These may be arranged thus:

1. *The Trifacial.*
2. *The Pneumogastric.*
3. *The Spinal.*

But if these constitute the *excitor* nerves of inspiration, the medulla oblongata must be viewed as the organ which combines the various muscles into a system, and the various nerves comprised in the respiratory system of Sir Charles Bell, are the true *motory* nerves of respiration. I may take this

opportunity of remarking that, beautiful as it is, Sir Charles Bell's system of respiratory nerves is defective from *two* circumstances: first, it is confined to the motor nerves, of the respiratory system; secondly, it is confined to respiration, when it ought to be extended to the whole of that system which I have ventured to denominate excito-motory, and which relates, not to respiration alone, but to all the acts of ingestion and egestion. See Plate III., Fig. 2 and 3.

170. In the separated head of the turtle, an act of respiration is excited either by irritating the nostril, the larynx, or the cut surface of the spinal marrow. The action is alike—equally excited—in all.

5. *Closure of the Sphincter Ani.*

171. The sphincter ani and cervix vesicæ present precisely similar phenomena with the larynx and pharynx. In a horse, rendered insensible by a blow of the poll-axe, the sphincter was immediately forcibly contracted, and the tail raised, on stimulating the border of the anus; these phenomena ceased either on separating the sphincter from its connexion with the spinal marrow, or on destroying the spinal marrow itself: the excitory and reflex action of the medulla, and its influence on the sphincter are therefore obvious. Dr. Alison describes the action of the sphincters, in one work [1], as dependent upon what he designates tonicity, a property of the muscular fibre; in another [2], as belonging to the class of sympathetic actions. It is plain from this discrepancy of opinion in the same author, that there was nothing definitive in our knowledge on this subject, until I proved that the action of the sphincters, like that of the orifices, depends on the excito-motory property, acting through incident, excitor nerves, the spinal marrow, and reflex, motor nerves.

[1] Outlines of Physiology and Pathology, Edinb. 1833; p. 7.

[2] British and Foreign Medical Review, vol. III. p. 33.

6. *Action of the Expulsors.*

172. If, in a turtle, after the removal of the tail and the posterior extremities, with the rectum, and of course with a portion of the spinal marrow, water be forced into the intestine, by means of Read's syringe, both the cloaca and the bladder are fully distended before any part of the fluid escapes through the sphincter, which it then does on the use of much force only, and by jerks. If, when the cloaca is distended, the integuments over it are stimulated, the water is propelled to a considerable distance. The event is very different on withdrawing the spinal marrow: the sphincter being now relaxed, the water flows through it at once, in an easy continuous stream, with the application of little force, and without inducing any distention of the cloaca. The action of the sphincter and of the expulsors of the cloaca in the turtle, and its dependence on the spinal marrow, are distinctly proved by this interesting experiment.

7. *Acts of Generation.*

173. Erection of the penis may be an excito-motory act. It was induced in the patients with injury or disease of the spinal marrow, whose cases have been already noticed, each time the catheter was introduced into the urethra; the patients themselves being unconscious either of the contact of the instrument or of its effect.

174. That the emission of semen depends upon the same excito-motory function of the spinal marrow is equally obvious. In ordinary circumstances it is excited through the influence of the nerve termed the dorsalis penis. It has been excited, in experiments made by M. Segalas, by acting immediately on the spinal marrow. "Si sur un cochon-d'Inde mâle, dont on a mis le cerveau à nu, dit ce physiologiste, on plonge un stylet dans le cervelet *de manière à arriver à la partie supérieure de la moelle de l'épine*, on produit *l'érection;* si l'on pousse ensuite le stylet dans la colonne vertébrale, jusque dans la région lombaire, *l'ejaculation* a lieu,

tandis que la vessie, fût-elle pleine, n'en conserve pas moins son dépôt. Les mêmes phénomènes s'observent dans les cochons-d'Inde décapités, quand on agit de même avec un stylet de haut en bas sur la moelle de l'épine[1]." This fact is confirmed by a remark of Mr. Earle,—that priapism exists in injury of the spinal marrow, only when that injury is in the *neck*.

175. I may revert to the case of the act of deglutition: deglutition cannot be performed several times in rapid succession, for want of the presence and stimulus of the saliva. In the same manner the act of ejaculation requires the *local* stimulus of semen.

176. That the grasp of the Fallopian tubes is excited on the same principle is extremely probable; and that the action of the uterus belongs to the same excito-motory system seems to be proved by the occurrence of the expulsion of the fœtus after the cessation of respiration. Such an event is noticed by Prof. Müller[2], and a recent case in point is given by Mr. Ingleby of Birmingham[3].

177. In this manner we observe, that whilst all the orifices of the animal frame with the acts of ingestion are under the influence of the reflex, excito-motory function of the spinal marrow, the sphincters and expulsors also act as parts of the same system. A plan of the nerves of this part of the system is sketched in Pl. III. Fig. 3.

8. *The Tone of the Muscular System.*

178. There is another phenomenon belonging to this system which demands our attention,—the tone of the muscular fibre throughout the animal frame. Two rabbits were taken: from one the head was removed; from the other also the head was removed, and the spinal mar-

[1] Anatomie du Cerveau, par M. Serres, tome ii. p. 608.

[2] Handbuch, I. 696.

[3] Obstetric Medicine; p. 44, 45.

row was cautiously destroyed by a sharp instrument; the limbs of the former retained a certain degree of firmness and elasticity; those of the second were perfectly lax. The difference was most obvious. On the following day, the limbs of both were found equally rigid from the contraction of the muscular fibre from its irritability.

179. The dependence of the muscles on the influence of the spinal marrow, for tone, is extremely obvious in the turtle.

180. The limbs and tail of a decapitated turtle possessed a certain degree of firmness or tone, recoiled on being drawn from their position, and moved with energy on the application of a stimulus. On withdrawing the spinal marrow gently out of its canal, all these phenomena ceased. The limbs were no longer obedient to stimuli, and became perfectly flaccid, having lost all their resilience. The sphincter lost its circular form and its contracted state, becoming lax, flaccid, and shapeless. The tail was flaccid, and unmoved on the application of stimuli.

181. It is perfectly obvious from this experiment, that the tone of the muscular system, and the action of the limbs on the application of stimuli to the skin, are modifications of the same function. Both co-exist, or cease, with the spinal marrow.

9. *The Seat of the Passions.*

182. There is good reason to conclude, as I have already stated, that the cerebrum is the seat of the ψυχη and of the *intellectual faculties.* There is equally good reason to believe that the medulla oblongata is the seat or nervous organ of the manifestation of the *appetites* and *passions.*

183. In the idiot, in whom the cerebral lobes are struck with such atrophy and defective development as to annihilate every vestige of intellect, the appetites and passions are frequently not only unimpaired, but un-

naturally strong: the appetite for food, sexual excitement, anger and terror, are manifested in their turns in a remarkable degree [1].

184. The arm which is totally paralyzed to volition or voluntary motion, in hemiplegia, is strongly agitated by surprise and other emotions. The seat of these emotions is, therefore, placed *lower* down in the nervous system, than the seat of volition and of the disease: the influence of volition is intercepted by that disease; whilst that of passion is manifested in the most distinct manner. The case is very different in paraplegia: here, the influence of the passions or emotion, as well as of volition, is totally cut off by the disease; that disease is, therefore, situated *below* the seats of volition and of the passions.

185. Have we not, in these cases, evidence of the actual seat of the passions? Is not this seat obviously placed *below* the seat of the disease in *hemiplegia*, and *above* that of the disease in *paraplegia?* and, if so, is not this seat the medulla oblongata?—the established centre and combiner of the acts of deglutition, and of respiration, acts so important in reference to the appetite for food, and for air, the latter of which is affected in so extraordinary a manner in the exercise of the remaining one,—and, indeed, in all the emotions and passions.

186. I mention this subject thus briefly only to propose it as a subject for future inquiry, in the course of these researches, and to render this sketch of the nervous system a little less incomplete. No one can see more clearly than myself how much remains for observation to accomplish.

187. It is interesting to remark, that the passions affect precisely those organs of ingestion and egestion which are known to be particularly under the influence of the spinal system: grief induces a painful sense of choaking; fear relaxes the sphincters; all the passions affect the respiration: a disgusting object induces sickness.

[1] See particularly Recherches sur l'Encéphale, par M. Lallemand; tome iii. p. 338-9.

III. *The Pathology of the Excito-Motory System.*

188. I now proceed to explain the application of these principles to pathology and practice.

189. Disease may take place in any of the three divisions of which the true spinal or excito-motory system consists: in the course of the incident, excitor nerves; in the spinal marrow, or centre of the system; or in the reflex, motor nerves. I shall very briefly adduce examples of each of these.

190. The action of disease, in the first of these cases, is incident, and either direct in its course, or from *above, downwards*, or retrograde, that is from *below, upwards*. It always induces a *spasmodic* affection. The action of disease, or of the causes of disease in the third is, I believe, never retrograde, and may induce either *spasm* or *paralysis*.

1. *The Cynic Spasm.*

191. The first fact which I shall adduce in illustration of these principles, is one to which I have ventured to apply the designation of the *Cynic Spasm*, for it is probably the σπασμος κυνικος of Hippocrates; and it is certainly allied to the Sardonic laugh. It is excited through filaments of the trifacial nerve (the "*nervi ethmoidalis ramus narium externus*[1]," the "*nervi lateralis narium superiores et inferiores*[2]"); these, when excited under particular circumstances, induce contractions of the levatores alæ nasi. In a patient in the deep coma of apoplexy, I pierced the skin on the cheek, the hand, the thigh, &c., with a pin; there was no manifestation of sensation—no motion whatever. I then touched the eye-lash and the *internal* nostril with a feather; this induced action of the orbicularis and levator alæ nasi; I then pricked the *exterior* part of the nostril with the pin; the action of the levatores was immediate.

[1] Arnold, Pl. viii. 26.

[2] Ibid. ix. 5.

2. *The act of Vomiting.*

192. A more familiar example of pathological excitement of the true spinal system is the act of vomiting. The *fifth* pair of nerves distributed upon the fauces, and especially the velum pendulum palati,—the pneumogastric in the stomach, the renal duct, and the gall-duct,—and spinal nerves in the rectum and uterus, are the several excitor nerves through the medium of which this act is excited.

193. It is important to remember, that it is the *fauces*, and not the pharynx, on which the excitor nerve of vomiting is distributed. From an ignorance of this fact, an act of deglutition has occasionally been induced, when an act of vomiting was intended to be excited. It has happened, for example, that when a patient has wished to excite vomiting by tickling the fauces with a feather, he has, by passing it into the *pharynx*, touched excitor nerves of another class and induced such an action of the muscles of deglutition, as has drawn it into the œsophagus. There are two interesting cases of this kind in the Medical Observations and Inquiries [1].

194. The other cases of excited vomiting are perfectly familiar to the physician. Certain substances taken into the stomach; a calculus in the renal duct or biliary duct; certain conditions of the rectum and of the uterus, are frequent causes of this excited act.

3. *Certain Forms of Asthma.*

195. Allusion has already been made § 149, to the result of an attempt to inhale pure carbonic acid gas. The larynx is instantly closed through the agency of the pneumogastric or internal excito-motory nerve. If, instead of carbonic acid, the powder of ipecacuanha, diffused in the atmosphere, be inhaled, it reaches the bronchia, and acting there upon the excito-motory system, induces contraction of the bronchial muscles and tubes, and a pe-

[1] Vol. iii. p. 7. and vol. vi. p. 231.

culiar form of asthma, impeding the acts of inspiration. Indigestible substances taken into the stomach, and fæculent matters retained in the intestines, induce, in a similar manner, but by dissimilar means, the same effect.

4. *Tenesmus; Strangury; &c.*

196. The expulsors and sphincters of the animal frame are liable to similar affections. A minute calculus, situated high up in the urethra, has induced such contraction of the sphincter ani, as almost to close the canal. A ligature upon a hæmorrhoidal tumor has induced absolute retention of urine. A source of irritation within the rectum, or within the bladder, frequently induces tenesmus, or strangury, or both. These phenomena are all induced through the spinal excitor and motor nerves. But a more extraordinary case of this kind is induced through excitor nerves more remotely situated. In a little boy, the nephew of Dr. Heming, strangury was induced, in the most unequivocal manner, by dentition. The case was supposed to be calculus. It was relieved at once by effectually lancing the gums.

5. *Crowing Inspiration and Convulsion.*

197. This last remark leads me to notice briefly other affections of infancy. Through the medium of irritation of the *fifth* pair of nerves in the gums during dentition, of the pneumogastric in the stomach, from undigested food, and of spinal nerves in the rectum, from the presence of matters too long retained or morbid in themselves, physicians frequently observe attacks of crowing inspiration, threatening suffocation, or of general convulsion, separately or consecutively. As minor parts of this singular affection of the excito-motory system, we observe the thumb drawn to the junction of the first and second phalanges of the fingers, so as to form a cone, and the toes drawn towards the sole of the foot.

198. It is no part of my present object to treat this subject professionally. But, as a further proof of the correctness of these views, I

may add, that early and effectually to relieve the gums, and to guard the stomach and intestines, in reference to the respective sources of irritation in these organs, constitute the certain means of removing and preventing these dreadful attacks.

199. It is important to observe, however, that convulsions, and even the crowing inspiration, instead of having their origin in excitor nerves, may arise from affection of the centre of the excito-motory system. In a case of spina-bifida, related to me by Mr. Herbert Evans, of Hampstead, there was a croup-like convulsion whenever the little patient turned, so as to press upon the *tumor*. In the case of anencephalous fœtus, described by Mr. Lawrence, convulsion was produced on pressing upon the medulla oblongata. In a case of meningitis, given by Dr. Abercrombie, the anterior fontanelle became very prominent, and pressure upon it induced convulsion.

6. *Epilepsy; Tetanus; Hydrophobia.*

200. The remarks which I have made, in reference to convulsions in infants, are applicable to epilepsy. This disease arises from causes acting through the medium of the excitor nerves, or upon the central part of the system, or the spinal marrow. In the former case the cause is seated in the stomach, the intestine, the uterus, and acts through excitor nerves. In the latter, it is seated within the cranium or spinal canal. In all, it acts directly or indirectly on the spinal marrow, the mediate or immediate source of all convulsive diseases. A brief paragraph will convey an idea of the important statement which I have just made, and which must be pursued on an occasion professedly medical.

201. It has been ascertained that, *in experiments*, lesions of the encephalon induce *paralysis only*, whilst lesions of the medulla oblongata and spinalis induce *convulsion* or *paralysis*, according to its severity. Hence it becomes an important question to determine the cause of convulsive affec-

tions in *disease* of the encephalon. This cause appears to be either irritation or counter-pressure: the former may act through the medium of the nerves distributed to the membranes,—as the recurrent of the fifth of Arnold,—as in epilepsy induced by a spicula of bone; the latter is illustrated by the case of meningitis by Dr. Abercrombie, already quoted, in which the anterior fontanelle became prominent; pressure upon it induced convulsion.

202. Tetanus is sometimes traumatic, that is, excited through the medium of a wounded excitor nerve; in other cases it is a disease of the spinal marrow itself. The former may be designated eccentric; the latter, centric tetanus. Dupuytren speaks of a young man, "qui périt des suites d'un violent coup de fouet, dont le nœud, détaché de la mèche, etait resté inséré dans le nerf cubital."

203. Hydrophobia is always eccentric.

204. The most remarkable circumstances in reference to all these diseases is, that they affect those organs precisely, which have already been mentioned, as most clearly manifesting the operation of the special function of the true spinal marrow—the organs of ingestion and of egestion, the orifices and sphincters, the limbs. How remarkable are the affections of the respiration in the crowing disease, in epilepsy, in tetanus, in hydrophobia! They sometimes threaten, sometimes actually induce, asphyxia. How remarkable is the affection of deglutition in hydrophobia, and of the expulsors in epilepsy! The functions, from being physiological, have become pathological.

7. *Spasmodic Strabismus, Tic, Torticollis, &c.*

205. These form the next series of pathological phenomena of the excito-motor system. As the former ones have their origin in the excitor nerves, or in the medulla itself, these have their seat in the motor nerves.

These nerves may be the seat of inflammation or of mechanical injury, and then we have the different local forms of spasmodic affections which I have enumerated.

206. I must not dwell upon this subject in this place. I will, therefore, only make one observation more. How important is it that these cases should be clearly distinguished from those of the two former classes, which involve the centre of the system, and a corresponding danger! Amongst these, how important is it to distinguish those cases which have their seat in the course of the nerves *within* and *without* the cranium or the spine!

8. *The Condition of the Muscles in Paralysis.*

207. The next subject to which I shall advert is one of the highest interest. What is the condition of those muscles, in the human subject, from which volition is cut off, in disease of the cerebral lobes, or of the spinal marrow,—in hemiplegia and paraplegia?

208. It is singular that a question, which now becomes so important, should have been hitherto entirely neglected. So true is it that facts of the most familiar kind acquire a new value when associated with an important principle.

209. In the case of hemiplegia, from disease of the opposite cerebral lobe, the skin may be entirely deprived of sensation, and the muscles of voluntary motion; the muscles are still, however, influenced by the *passions*. In perfect paraplegia, from injury or disease of the spinal marrow, not only the influence of volition, but that of the passions also, is entirely interrupted. In both, instead of the *cerebro-spinal* life with which the limbs were endowed before, a *spinal* life alone remains.

210. I was called to a patient a short period ago, affected at that moment with bronchitis. He was forty-three years of age; and at the age of twenty-four had been seized with hemiplegia. Recovering from the immediate danger of the attack, he remained hemiplegic, scarcely regaining

the use of the hand and arm at all, and only partially that of the leg.

211. Whenever this patient is excited by meeting an acquaintance, or in any similar way, he has a little strabismus, and the hand and arm are contracted and convulsed in the most extraordinary manner: whenever he coughs, the leg is thrown involuntarily upwards. The arm is severed, as it were, from *volition*, but affected by *emotion*.

212. In the case of which I shall next give a sketch, the lower extremities are severed at once from the acts of the will and the influence of the passions, and submit only to *excitory* influences. I am indebted for it to Dr. Budd. It was a case of nearly perfect paraplegia, sensation and voluntary power being nearly annihilated. On pinching the skin, and on tickling the sole of the foot, the most remarkable muscular contractions were induced; whenever the bowels were moved, these contractions in the limbs were so violent as to have rendered it necessary to have the feet bound down to the floor!

213. Another proof of the most singular character, must now be mentioned. When strychnine is administered to hemiplegic patients, it is the paralytic limbs which first feel its influence. What is the rationale of this phenomenon? Is it that, for want of the stimulus of volition, inducing voluntary actions, the irritability is greater in the paralytic than in the other limbs, in which it is continually diminished by these actions,—and that the muscles of the paralytic limbs are therefore more susceptible of the action of the excito-motory stimulus, and its augmentation under the influence of the strychnine?

214. Nysten [1] determined that the irritability of the muscles of a paralytic limb was as great as that of the sound limb. But experiments for determining the comparative irritability of the healthy and diseased limbs, more definitely, are still wanting.

[1] Recherches de Physiologie; Paris, 1811; p. 377.

9. *Failure of the Excito-Motory Power.*

215. In cases of typhus, of disease of the head, of exhaustion, of sinking—as the general powers of life decline, the gradual failure of the excito-motory power is particularly marked.

216. The first thing observed is, that the eye-lids do not perfectly close during sleep; they still, however, close on touching the eye-lash. In a short time, not only the continued action of the orbicularis is defective, but the excitability of the border of the eye-lid is impaired, and the orbicularis ceases to act on touching the eye-lash.

217. The second effect of a failing excito-motory power, is an affection of the respiration. This is first *audible*, as in sleep. It then ceases to be *equable*, and at length consists in sudden, *catching*, inspirations,—a state from which I never knew a patient recover.

218. In the next place the sphincters lose their power.

IV. *The Therapeutics of the Excito-Motory System.*

219. The discussion of the therapeutics of the excito-motory system must, for obvious reasons, be confined within very narrow limits.

220. The principal applications of the therapeutics of the excito-motory system, is in the treatment of asphyxia, of certain kinds of convulsion, of sickness, of asthma, of impaired power of the sphincter vesicæ.

221. In some cases of asphyxia, and especially in the case of the asphyxia of the newly-born infant, the excitement of the trifacial, or spinal nerves by exposure to the cold atmosphere, or dashing cold water on the face or trunk, is a most important remedy. We may also irritate the nostrils, the fauces, or the glottis, and attempt to excite the actions of

sneezing, vomiting, and coughing. Galvanism may be applied with similar views.

222. The occurrence of convulsion is frequently prevented, and the larynx, closed in certain convulsions, is opened, by dashing cold water over the face.

223. Sickness and vomiting, even at sea, are sometimes prevented by the full exposure of the face to the cold breeze.

224. Asthma is sometimes removed by the inhalation of certain vapours, as the smoke of the stramonium, the vapour of creosote, &c.

225. Enuresis has been remedied by the action of cantharides.

226. The special action and application of strychnine and of the hydrocyanic acid still require to be fully investigated. Of the effects of the former I may add the following interesting case:

227. "A lady being at Lausanne, in September last, consulted a foreign physician there, who prescribed the strychnine. I do not know the dose. I only know that it was afterwards *diminished* to one-tenth of a grain thrice a day.

228. "Two pills were taken at bed-time, and three the next morning; soon after which the patient was taken with spasm of the muscles about the larynx and those of one arm. She felt as if strangled. With much effort she mixed some *Eau de Cologne* with water, 'snapped at it,' and so swallowed it. She was shortly relieved. The dose of strychnine was repeated between breakfast and at noon. The same symptoms were renewed; she *felt* and *looked* as if strangled. The muscles on each side of the larynx became tense, like chords. She was again relieved by *Eau de Cologne*, which she took hastily, as before.

229. "After this, the dose of strychnine was reduced, as I have stated, and was taken without any bad effect[1]."

[1] See the Lancet for November 8, 1834.

TABLE OF THE NERVOUS SYSTEM, IN RELATION TO MOTION.

Psychical, and not Excito-Motory.

I. The Functions of the Cerebrum and of the Sentient and Voluntary Nerves.

- 1. Sensation-inducing
  - Motion—through
    1. Volition.
    2. Emotion.
- 2. Volition, &c.
  - 1. Its constant,
  - 2. Its occasional, Influence, on the Muscular System.

Diseased conditions.

1. 1. Painful Tic.
   2. Anæsthesia.
2. 1. Delirium.
   2. Coma.
3. Paralysis of Voluntary Motion.

1. Inert in Utero.
2. Diminished or suspended during Sleep.

Excito-Motory, not Sentient or Psychical.

The principle,—the *Vis Nervosa* of Haller,—*Electricity*?

II. The Functions of the True Spinal Marrow and of the Excitor and Motor Nerves.

Excited Motions.

1. In the Motor Nerves.
   1. Experiment.
   2. Spasmodic Tic.
   3. Torticollis, &c.
2. *Direct*, in the Spinal Marrow.
   1. Experiment.
   2. The Tone of the Muscular System.
   3. Some Effects of the Passions.
   4. The Centric Diseases of the Spinal Marrow.
3. *Retrograde*, in the Spinal Marrow. — Experiment.
4. *Incident, Retrograde, Direct, Reflex*, COMBINED, in the Excitor Nerves, Spinal Marrow, *and* Motor Nerves.
   1. Typical Experiment.
   2. Experiments of Redi, Whytt, Legallois, Mayo, &c.
   3. Physiological Phenomena.
      1. Of the Eye-lids.
      2. Of the Orifices
         1. The Larynx.
         2. The Pharynx.
      3. Of the Ingestion.
         1. Of Food; 2. Of Air; 3. Of Semen.
      4. Of Exclusion.
      5. Of the Expulsors, or Egestion.
         1. Of the Fæces; 2. Of the Urine; 3. Of the Semen; 4. Of the Fœtus.
      6. Of the Sphincters.
   4. Eccentric Diseases of the Spinal Marrow.
      1. 1. Of Dental.. 2. Of Gastric.. 3. Of Intestinal — Irritation in Infants.
      2. 1. Of Gastric.. 2. Of Intestinal 3. Of Uterine — Irritation in Adults.
      3. Traumatic Tetanus,
      4. Hydrophobia, &c.
      5. Effects of some medicines, as
         1. Strychnine.
         2. Hydrocyanic Acid.

1. Active in Utero.
2. Active during Sleep.

Unattended by obvious Motions.

III. The Functions of the Ganglionic System.

1. Formation.
2. Nutrition.
3. Secretion.

Diseased conditions.

1. Augmentation.
2. Diminution.
3. Derangement.
4. Paralysis.

1. Active in Utero.
2. Active during Sleep.

Sect. VIII.—*The Ganglionic, or Secretory System.*

230. I think that there is good reason for viewing the fifth and the posterior spinal nerves as constituting an external ganglionic system, for the nutrition, &c. of the external organs; so that I would propose to subdivide the ganglionic subdivision of the nervous system into—

I. *The External*, comprising
   1. *The Fifth;*
   2. *The Posterior Spinal.*

II. *The Internal*, comprising
   1. *The Sympathetic;*
   2. *The Pneumogastric.*

231. The ganglia upon the nerves were first observed to be attached to the portio major of the fifth and the posterior spinal nerves, not, as Sir Charles Bell states[1], by Monro, but by Prochaska. This latter author observes, in the preface to a republication of his work in 1800:—

232. "Hic tractatus, qui anno 1779 prodivit, plures novas observationes circa structuram systematis nervosi a me factas continet. Harum nonnullæ, quibus in textu non fuit locus, in explicatione figurarum uberius exponuntur, ad quas spectat nova arbor vitæ corporum olivarium, vid. Tab. I. Fig. 3, 4, 5; fasciculus funiculorum nerveorum quinti paris cerebri, qui insalutato ganglio semilunari sub eodem tertium ramum ejus nervi maxillarem inferiorem dictum petit, vid. Tab. II. Fig. 4, 5; sic quoque radices anteriores omnium nervorum spinalium, quæ insalutata ganglia radicum posteriorum transeunt, vid. Tab. III. Fig. 1, 2. Super eandem materiem plura præclara scripta isto tractatu serius in lucem prodivere, inter quæ præcipue *Monroi Observations on the Structure and Functions of the Nervous System* (1783); *Soemmeringi Ueber das Organ der Seele, Königsberg*, 1796;

[1] The Nervous System, 1830, Pref. p. vii, &c.

et *Reilii Exercitationes Anatomicæ de Structura Nervorum*, 1797, adnotari merentur."

233. I am not aware that any preceding inquirer has suggested the real office of the ganglia on the fifth and posterior spinal nerves.

234. Prochaska asks, p. 353, "Quis rationem dabit:" ... "Quare radices anteriores nervorum spinalium ganglia spinalia insalutata transeant, et quare nam solæ posteriores radices ganglia spinalia tranare cogantur." ... "Quare omnium cerebri nervorum solum quintum par post ortum suum more nervorum spinalium ganglion semilunare dictum facere debet, sub quo peculiaris funiculorum fasciculus ad tertium quinti paris ramum maxillarem inferiorem dictum, properat insalutato ganglio semilunari ad similitudinem radicum anteriorum nervorum spinalium?"

235. Sœmmering has asked similar questions. Sir Charles Bell has quoted Prochaska, and Sœmmering, and Scarpa, in a tone of exultation; but I confess that to me it appears that that justly celebrated physiologist has not approached any nearer to the solution of these questions than his predecessors. Sir Charles Bell has, I believe, distinctly proved the difference of function between the anterior and posterior spinal nerves, and between the respiratory and other nerves—brilliant discoveries—which will, as long as anatomical and physiological science last, perpetuate the memory of his genius; but there is no connection between the function of sensation and the existence of a ganglion[1]; and the unequivocal sentient nerves, as the olfactory, the optic, the auditory, are without any thing very distinct of this kind.

236. The questions, then, still remain, why are the portio major of the fifth, especially, and of the posterior spinal nerves provided with ganglia? The reply to these questions, and the argument, may be stated thus:—

[1] See Swan's Comp. Anat. of the Nerves, p. 26.

237. 1. There is an internal nerve for formation, nutrition, secretion, &c. 2. This nerve is ganglionic. 3. There are external organs and structures requiring nutrition, &c. 4. There are also external ganglionic nerves. The inference is plain, that these constitute the external ganglionic subsystem. The fifth especially abounds with ganglia.

238. It is true that the semilunar and external spinal ganglia differ in appearance from the ganglia of the sympathetic, as Sir Charles Bell has well displayed. What is the nature of this difference? To this question I find no reply in authors. It is plain, however, that the difference consists in their being, alone, *plexic*. The internal ganglionic nerve is purely nutrient: its ganglia are simple. The external involve sentient, and I believe excitory, nerves, with the nutrient; they combine, therefore, the appearances of the plexus and of the ganglion.

239. I must add another argument upon this point. If the sensation of the face be lost by paralysis, arising from disease of the *brain*, the eye is safe; but if the same event occur from compression or destruction of the *fifth*, *within* the cranium, by disease, or in an experiment, the eye ceases to be nourished, and becomes destroyed! In the former case the nerve of sensation merely has suffered; in the latter the nerve of nutrition, as well as sensation, has been involved in the disease or injury [1].

240. I will conclude these observations by adducing the following interesting Table from Mr. Clark's work on the Nervous System [2].

[1] See my "Lectures," p. 120; 166, &c.

[2] The Practical Anatomy and Elementary Physiology of the Nervous System; by F. Le Gros Clarke, Demonstrator of Anatomy at St. Thomas's Hospital. 1836; Introd. p. xiii.

MR. F. LE GROS CLARK'S TABLE OF THE NERVOUS SYSTEM.

	Cerebral.			Excito-motory.		Sympathetic.	
	Voluntary Motion.	Common Sensibility.	Specific Sensibility.	Excitor.	Motor.	Involuntary Motion.	Assimilation.
Olfactory			*				
Optic			*				
Common Oculo-muscular	*				?		
Pathetic	*				*		
Trigeminal { ganglionic portion		*		*			?
Trigeminal { nonganglionic portion	*				*		
Abducent	*				*		
Facial	*				*		
Auditory			*				
Glosso-pharyngeal			*?				
Pneumo-gastric	*			*	*		?
Spinal accessory	*				*		
Lingual motor	*				*		
Cervical plexus	*	*		*	*		?
Axillary Plexus	*	*		*	*		?
Dorsal Nerves	*	*		*	*		?
Lumbar Plexus	*	*		*	*		?
Sciatic Plexus	*	*		*	*		?
Facial Ganglia						*	*
Cervical Ganglia						*	*
Thoracic Ganglia						*	*
Abdominal Ganglia						*	*
Pelvic Ganglia						*	*

241. I will take this opportunity of stating, that *before* Prof. Müller's sanction of my views was known in this country, Mr. Clark perceived and avowed their importance and novelty with a candour which I would gladly see prevailing in every philosopher.

242. I must give similar praise to my pupil and friend, Mr. W. F. Barlow, to whom I am also indebted for an interesting case illustrative of my views. See § 74.

Sect. IX.—*Conclusion.*

I. *Proposed New Inquiries.*

243. In conclusion I must observe that this paper still only presents a sketch of the true spinal or excito-motory system. Each Section presents us with a subject which, if fully investigated, would form a distinct Memoir.

244. If I have succeeded in showing that the function of the true spinal marrow is not only distinct from sensation and voluntary motion, but identical with the vis nervosa, we may commence inquiries in another direction: What is the hidden agent in that function? Is it *Galvanism?* Does the establishment of a system of incident and reflex nerves, in connection with the true spinal marrow, suggest any experiments? These are questions which could not be entertained, even, whilst the phenomena were supposed to belong to sensation or other faculty of the soul.

245. As each nerve of the excito-motory system, with the exception, perhaps, of the pneumogastric, is a compound nerve having a cerebral as well as a true spinal origin, it becomes an interesting question whether these may be traced by the scalpel. This question is peculiarly interesting in reference to the trifacial and facial nerves. Experiment and pathology have already shown us, that the cerebral part of the function of these nerves may be obliterated, whilst the excito-motory property remains in them unimpaired [1].

246. But we have other means still of investigation. A mechanical, or the galvanic stimulus, or heat, applied to the excito-motory system, induces immediate contraction in a system of muscles, in a limb, or in a single muscle, according as an incident nerve, the centre of the system, or a motor

[1] See particularly my "Lectures," § 73—75.

nerve, is exposed to their influence. Strychnine induces a continued state of tetanus of the whole excito-motory system, which ceases entirely, or in parts, according as the centre of the system, a part of it, or a motor nerve, be divided or destroyed.

247. These agencies afford us, therefore, *means* of investigation. They are, in reference to the blended anatomy of the excito-motory system, what the scalpel is to the anatomy of other systems.

248. Facts in the blended anatomy, thus ascertained, may lead to the discovery of strictly anatomical facts, in the *Articulata*, or other Classes, in which the anatomy of the different nervous sub-systems may be distinct.

249. It will be interesting to apply these tests of the excito-motory power to the different parts of the nervous system in the different classes of animals.

250. It will be interesting to ascertain what internal surfaces, besides the mucous,—as the dura mater [1],—are supplied by excitor nerves.

251. It will be interesting, especially, to ascertain what are the *excitors and motors of respiration* in the different classes.

252. It will be interesting to ascertain the distinct *excitors* and *motors* of the *orifices* and of the *sphincters*.

253. Besides these and other *physiological* inquiries, the pathology and the therapeutics still open wide fields for investigation.

254. I repeat that *each* of these subjects will afford ample scope for a distinct Memoir. Their investigation cannot fail to lead to new views, and again to new inquiries. I shall not be deterred from the prosecution of the important subject.

[1] Supplied by the recurrent of the trifacial,—Arnold, Icones Nervorum Capitis.

II. *Recapitulation.*

255. To obviate all misapprehension relative to the claims of this paper, and to the views which it sets forth, I will now recapitulate briefly, but distinctly, the principal objects and results of my inquiries.

256. 1. My *first* object is the *distinction* of the excito-motory property from sensation, volition, instinct, and all functions of the cerebrum, or of the $\psi\upsilon\chi\eta$, or mind;

257. 2. My *second* object is the *distinction* of this property from the vis insita or irritability of the muscular fibre;

258. My *third* object is the *distinction* of this property as a function of—

1. *A true spinal marrow, and*
2. *A system of excitor and motor, and excito-motory nerves*, exclusively of the *cerebrum*;

259. 3. My *fourth* object is the *identification* of the excito-motory property with the *motor power* exercised by the spinal marrow and muscular nerves, when stimulated, upon the muscles to which they are distributed in their *direct* course,—the *vis nervosa* of Haller;

260. 4. My *fifth* object has been to prove that the excito-motory property acts in an *incident*, *retrograde*, and *reflex* course along incident nerves, when the *first* of these are stimulated mechanically, or by galvanism, in experiments, or by the natural stimuli in the living animal;

261. 5. This investigation has led to the suggestion of a corresponding anatomy, consisting

1. *In some portions of the spinal marrow*,
2. *In incident excitor nerves*, and
3. *In reflex motor nerves*,

distinct, in some instances, even in the *Mammalia*, from the sentient and voluntary nerves, as in the pneumogastric or internal excito-motory nerve,—and probably distinct altogether in the *Invertebrata*.

262. 6. My *sixth* object was the prosecution of the physiology, as seen in the action of the orifices, the sphincters, the ingestors, the expulsors of the animal economy, in general;—in the theory of the renewed acts of respiration *excited* by the contact of carbonic acid with the pneumogastric nerve;—in the view of the spinal marrow, as the *combiner*, in all the complicated acts of ingestion, egestion, &c. as the source of the tone of the muscular system, as the seat of the passions, emotions, &c.

263. 7. My *seventh* object was to ascertain the relation of the excito-motory property to pathology,—to the class of diseases originating in the excitor nerves, the spinal marrow itself, and the motor nerves. In a word, to *the entire Class of convulsive diseases;*

264. 8. My *eighth* object was the inquiry into the therapeutics of the excito-motory property, as evinced in the action of strychnine, of cantharides, of hydrocyanic acid, &c.; and into the mode of action of certain *causes* of disease, as dentition, irritation, wounds of nerves, &c.

265. 9. I may add also that the excito-motory principle affords a systematic *Classification* of an extensive series of experimental facts, and of physiological, pathological, and therapeutic phenomena, previously entirely *unarranged.*

266. 10. Finally, it is the establishment of the *principle* and of the special *organic seat*, and the developement of the *Theory*, or *System*, of the excito-motory phenomena, and by no means *all* the *facts* or *phenomena* themselves, which I claim as the peculiar result of my own labours.

THE END.

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"These observations are new, and denote a decided advance in our science."—*Professor Müller; Handbuch der Physiologie*, vol. i. p. 688.

EXPLANATION OF THE PLATES.

PLATE I.

PLAN I. Fig. 1 and 2. Experiments of Haller and the older physiologists, showing the operation of the *vis nervosa* in the direction of the nervous fibres.

Fig. 1. Action of the vis nervosa along motor nerves.

Fig. 2. Action of the vis nervosa along the spinal marrow and motor nerves, taking their rise *below* the point irritated.

PLAN II. Fig. 1, 2, 3, and 4. *New* experiments, of the author, showing the action of the *vis nervosa* in directions *incident*, *retrograde*, and *reflex*, not known to former physiologists.

Fig. 1. Action of the *vis nervosa* in a retrograde direction from the point irritated.

Fig. 2. Fig. 1. PLAN II, and Fig. 2. PLAN I. combined, demonstrating that it is the *same* power which acts in the retrograde direction, in the author's experiments, and in the direction of the nervous fibres in the experiments of Haller, &c.

Fig. 3. Experiments showing that the excito-motory power acts in an *incident* direction, *from* the point of a nerve irritated, *into* the spinal marrow; and thence, in a *reflex* direction, *to* the muscular fibres.

Fig. 4. Experiments showing that the *same* excito-motory power acts from the *cutaneous surfaces*, in the same *incident*, *retrograde* and *direct*, and *reflex* courses. (See p. 48; § 21.)

PLAN III; Fig. 1, 2, 3, 4, 5, 6, and 7. Experiments proving that these actions take place along *incident nerves*, the *true spinal marrow*, and *reflex nerves*, ceasing, as they do, wherever the *first*, Fig. 5, the *last*, Fig. 6, or *both*, Fig. 7, are divided, or the *second* Fig. 3, 4, is discharged.

PLAN IV; Fig. 1, 2, 3, and 4. Experiments proving the action of the excito-motory power along nerves and points of the spinal marrow, situated on the same parallel, or nearly so, Fig. 1 and 2; and along nerves so situated as to imply, in some cases, Fig. 3, a *direct*, in others, Fig. 4, a *retrograde*, course along the true spinal marrow.

Plate II.

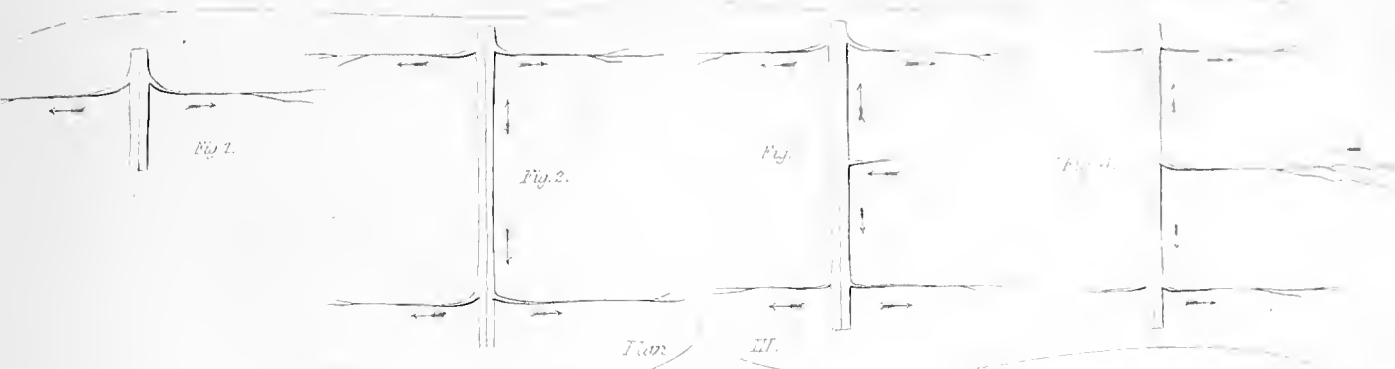

Plate III.

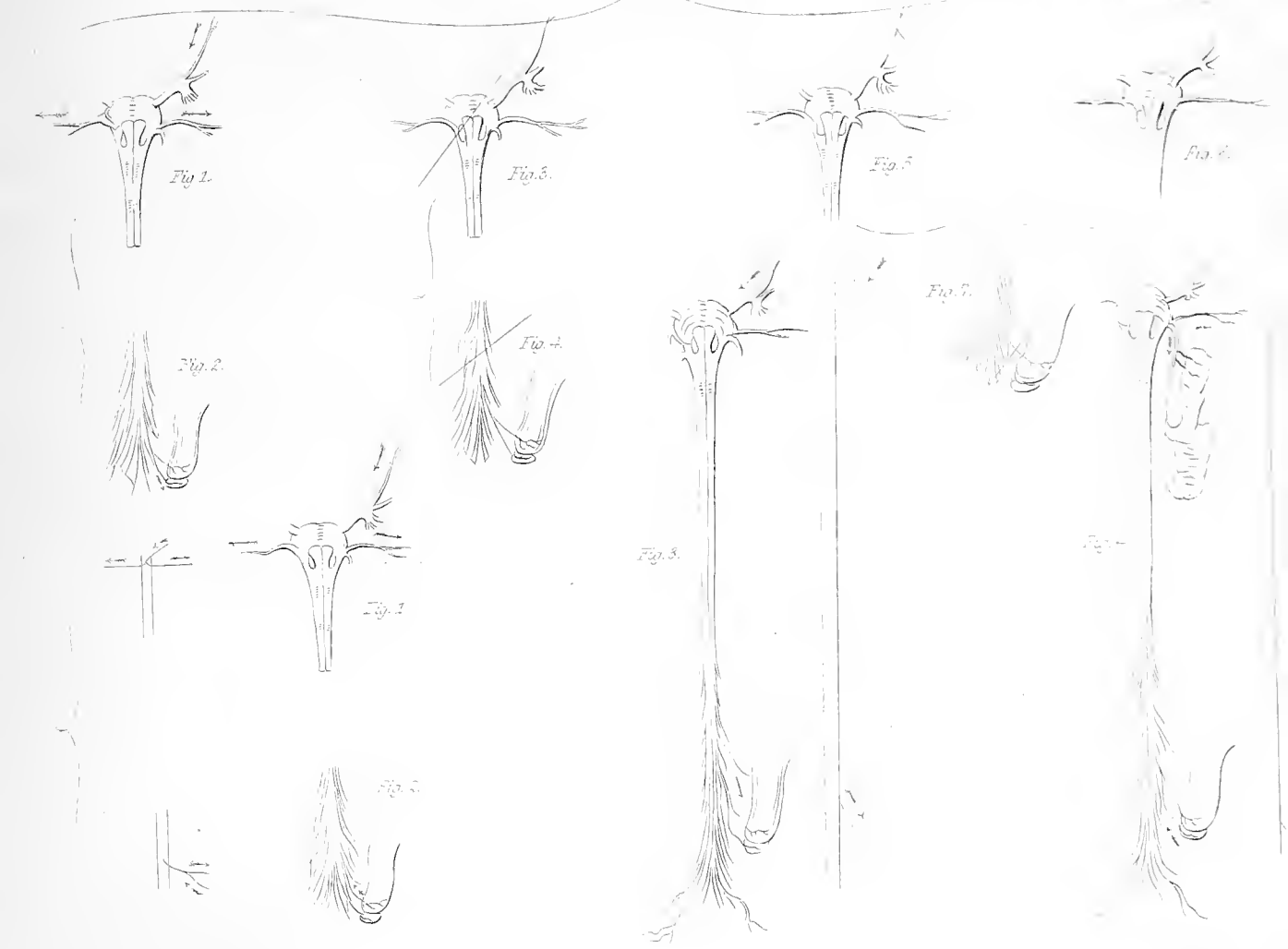

PLATE II.

This Plate presents a Plan of the True Spinal Marrow Excito-motory System of Nerves.

The Incident, Excitor Nerves, viz. the Trifacial, the Spinal, &c., are placed on the left hand.

The Reflex, Motor Nerves, the trochlearis, the abducens, the facial, the intercostal, the diaphragmatic, and the spinal, on the right.

The Pneumogastric is represented and designated as the *Internal Excito-motory Nerve*.

The principal branches of each of these nerves are enumerated in the *Table* given at p. 80, and well-known to every anatomist.

P.S. I wish to lay particular stress upon the *designations* which I have employed—*the True Spinal Marrow*, with its *Excito-motory System of Nerves;* these terms convey the true idea of the *System*, its *Anatomy*, its peculiar *Property*, and its *Reflex mode of action*.

Plan of the True Spinal or Excito motory System.

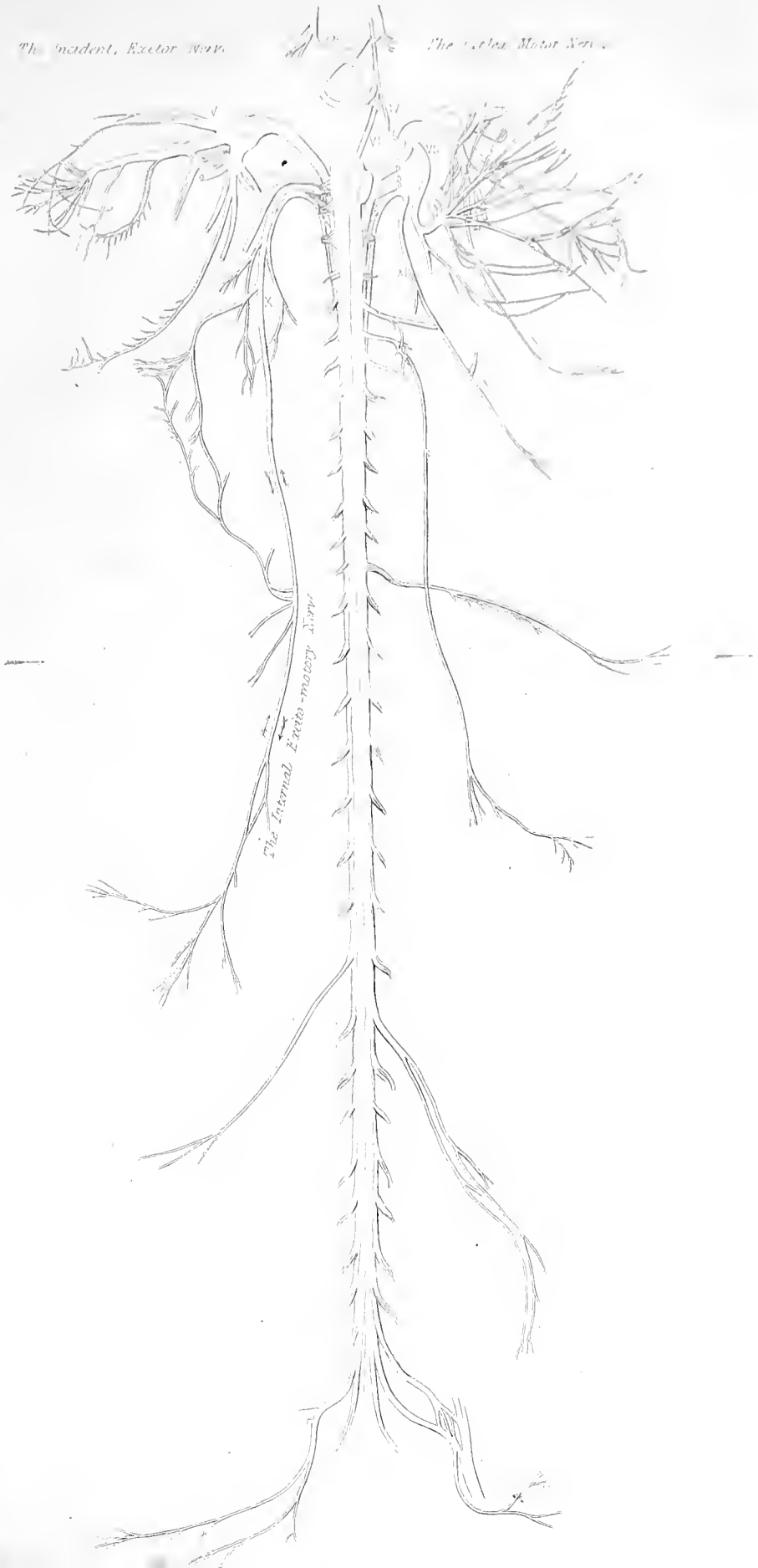

PLATE III.

Fig. 1 represents the *Cerebral System*, comprising the *Sentient* and *Voluntary nerves:* the former proceed *into* the *cerebrum;* the latter *from* the *Cerebrum*: see p. 37; 49—52; 72, 73.

Fig. 2 represents the *True Spinal System*, of *Excitor* and *Motor*, or *Excito-motory Nerves:* the Excitor nerves proceed *into*, the Motor nerves *from*, the *True Spinal Marrow*: see p. 37; 49—52; 80.

If the second Plan be folded and *superposed* upon the other, they will give a distinct idea of the *Cerebro-spinal System*, as it exists in Nature. We shall thus have a distinct idea of the *Double Cerebro-spinal* terminations, and origins, of the *Sentient* and *Excitor*, and of the *Voluntary* and *Motor* nerves.

See Lectures on the Nervous System, p. 33.

Fig. 3 denotes the actions of the *Excitor* and *Motor* nerves as the *guards* of the Orifices and Sphincters: see p. 79, § 136.

Fig. 4 represents the *Excitors* and *Motors* of *Inspiration:* see p. 77, § 127; fig. 5 the *Excitors* and *Motors* in the act of *Vomiting*, which is an excited act of *Expiration*, the larynx being closed: p. 97, § 192.

Cerebral System

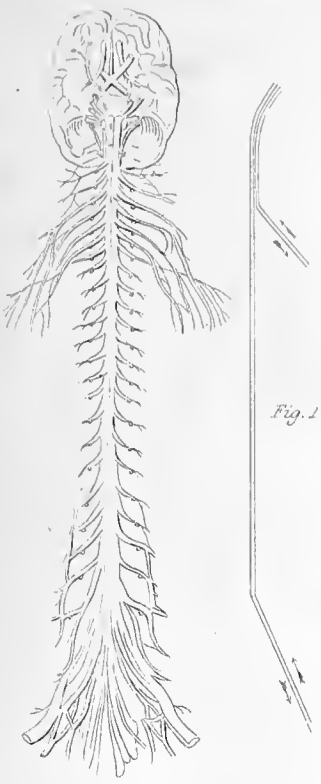

Fig. 1

Fig. 2

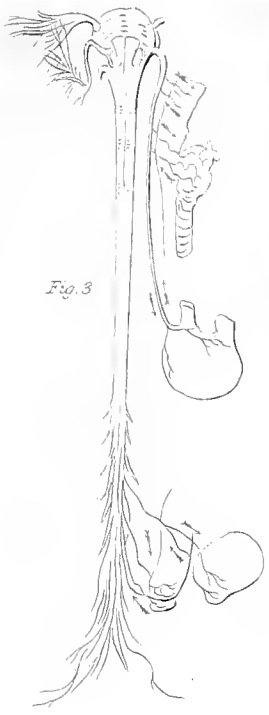

Fig. 3

Inspiration

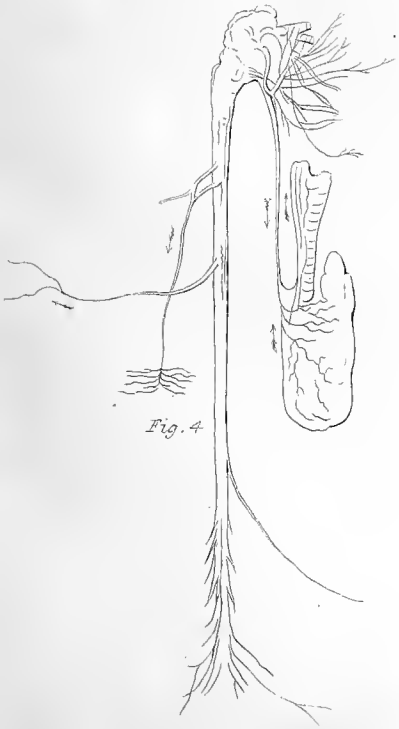

Fig. 4

Vomiting

Fig. 5

ERRATA.

Page 44, to note 11, add "Journ. de Phys., t. iv. p. 170, 312; t. v. p. 37;" and to note 12, add "Handbuch der Phys. p. 623."

After the word "nerves," p. 112, § 260, l. 3, insert "the true spinal marrow, and reflex nerves."

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